THE UNIVERSITY OF ALBERTA

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SLAVE LAKE, [illegible], CANADA

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA

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THE UNIVERSITY OF ALBERTA

STUDIES ON THE LOWER APHEBIAN, EAST ARM OF GREAT SLAVE LAKE, NORTHWEST TERRITORIES, CANADA.

by

Ⓒ MOSES AYODELE DELESON OLADE, B.Sc. (Hons.)

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Thesis

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Studies on the Lower Aphebian, East Arm of Great Slave Lake, Northwest Territories, Canada", submitted by Moses Ayodele Deleson Olade, B.Sc. (Hons.), in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

This thesis presents the results of studies on aspects of the stratigraphy, structure, mineralization and petrochemistry of Lower Aphebian rocks exposed within certain areas of the East Arm of Great Slave Lake, Northwest Territories.

In the Toopon Lake map-area, the Lower Aphebian sedimentary-volcanic sequence belongs to the Sosan and Kahochella Groups. Detailed geologic mapping and stratigraphic descriptions of the exposed lithostratigraphic units are augmented by petrographic descriptions of selected lithologies. The uranium-bearing Kluziai Formation is composed of sandstones and conglomerates deposited by WSW-flowing, braided streams which derived their sedimentary material from a predominantly plutonic terraine to the NE of the region.

The volcanic rocks and pyroclastics of the Seton Formation which occur in the upper part of the Lower Aphebian sequence constitute a principal phase of Proterozoic volcanism in the East Arm (structural) subprovince. Earlier described as 'greenstones' or basalts, and recently as an andesite-rhyolite suite, the Seton volcanics are now proved to possess a spilitic-keratophyric affinity. Petrographic descriptions of the lavas and pyroclastics from Toopon Lake, the Fort Reliance area and Seton Island (type section) are augmented by partial chemical analyses of fifteen lavas from the latter locality. The Aphebian Coronation Geosyncline during Seton times was therefore characterized by partially submarine

effusive volcanism associated with a small volcanic island complex. Also, the apparent contemporaneity between the Seton volcanism in the SW of the basin and shallow marine deposition of the upper members of the Sosan Group suggests that the Seton Formation should be re-classified into the Sosan Group,rather than the Kahochella Group.

Peneconcordant 'sandstone-type' uranium mineralization is localized within the Middle Member of the Kluziai Formation in the Toopon Lake area. A characteristic mineral assemblage of pitchblende-graphite-pyrite-chalcopyrite is dissemninated within the interstices of the host sandstone. The mineralization is epigenetic, but no hydrothermal alteration was observed. A genetic model is proposed, in which uranium, during spilitization and devitrification (diagenesis) of the Seton volcanics, was leached, transported and deposited within porous, braided-channel deposits, by connate solutions as a result of changes in pH and/or Eh, effected in part by the action of organic matter.

ACKNOWLEDGEMENTS

The writer is highly indebted to Dr. R. D. Morton for his supervision and interest in this thesis. Grateful acknowledgement is made to Dr. H.Baadsgaard for supervising the wet chemical analyses.

Permission for this study from Vestor Explorations Ltd. is highly appreciated. The writer is grateful to Mr. F. Dimitrov who did most of the drafting and Mrs. B. Maclean who typed the manuscript.

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CHAPTER ONE

INTRODUCTION

General Statement

Recent economic interest in the Lower Aphebian rocks of the East Arm of Great Slave Lake has been centred around the occurrence of epigenetic 'sandstone-type' uranium mineralization within the Hornby Channel and Kluziai Formations of the basal Sosan Group.

Vestor Explorations Ltd. recently made substantial uranium discoveries within the Simpson Islands, Toopon Lake and the Fort Reliance areas. The distribution of these radioactive occurrences along a 125 mile belt, extending from the southwest to the northeast of the region suggests that the East Arm may possibly be a uranium province of moderate to high potential.

The initial objective of this investigation was to carry out a geochemical and petrologic study of the volcanic and pyroclastic rocks (Seton Formation) associated with the uranium-bearing rocks, in the hope of elucidating any minerogenetic relationship between the volcanics and the epigenetic uranium mineralization. This objective was later modified and the scope of the investigation was broadened to include a study of the geology and uranium mineralization in the Toopon Lake area.

Methods and Scope of Investigation

This investigation involves studies on the strati-

graphy, structure, mineralization and geochemistry of Lower Aphebian rocks exposed within certain parts of the East Arm, Great Slave Lake.

The field aspect of this investigation was initiated with detailed field-mapping of the Toopon Lake area, where apart from well-preserved exposures, substantial uranium mineralization is localized within Lower Aphebian sandstones. Epigenetic, 'sandstone-type' uranium mineralization is rarely found in Canada, and even less so in Precambrian rocks. Therefore, a more detailed study of the stratigraphy and sedimentation of the ore-bearing Kluziai Formation was carried out.

Stratigraphic sections were measured and described, and rock samples representative of most lithologies were collected for thin-sectioning and petrographic examination. A few mineralized samples were collected from blasted trenches for polished-sectioning and X-ray studies. Due to the fine-grained and disseminated nature of the mineralization, it was difficult to concentrate enough radioactive material for X-ray diffraction analysis.

The volcanic rocks of the Seton Formation constitute a part of the Lower Aphebian sequence in the East Arm. In Toopon Lake, pyroclastics of this Formation overlie the uranium-bearing rocks. In a search for the 'source' of this regionally distributed uranium mineralization, a study of the petrochemistry and petrography of the Seton volcanics was initiated. As relatively little is known about the petrology of these volcanic

rocks, geologic mapping in Seton Island (type section), Toopon Lake, Lac Duhamel and the Fort Reliance area by the author and Dr. R.D. Morton was augmented by a petrographic study of selected samples from these areas.

Chemical analyses of the lavas from Seton Island were performed by wet chemical and X-ray spectrographic methods, utilizing in the latter case, a heavy absorber matrix. An initial plan for examining the U-Th ratios in the volcanics was dropped, owing to the fact that a precise gamma-ray spectrometer was not available.

Location and Accessibility of Study Area

Most of the field aspects of this investigation were carried out in the Toopon Lake map-area which is situated just south of McLean Bay, in the East Arm of Great Slave Lake, N.W.T. The study area (Fig. 1) lies approximately between longitudes 110° 20' W to 110° 32' W and latitudes 62° 19' to 62° 22'. It is easily accessible from Yellowknife, Hay River or Fort Smith by chartered aircraft. The thesis area can also be reached by water, through Snowdrift River and McLean Bay, from various points on Great Slave Lake.

Figure 2 is the index map of the study area, and it shows existing geographic names and those assigned for the purpose of this investigation.

The location of Seton Island and the Fort Reliance area from where various samples of the Seton volcanics were

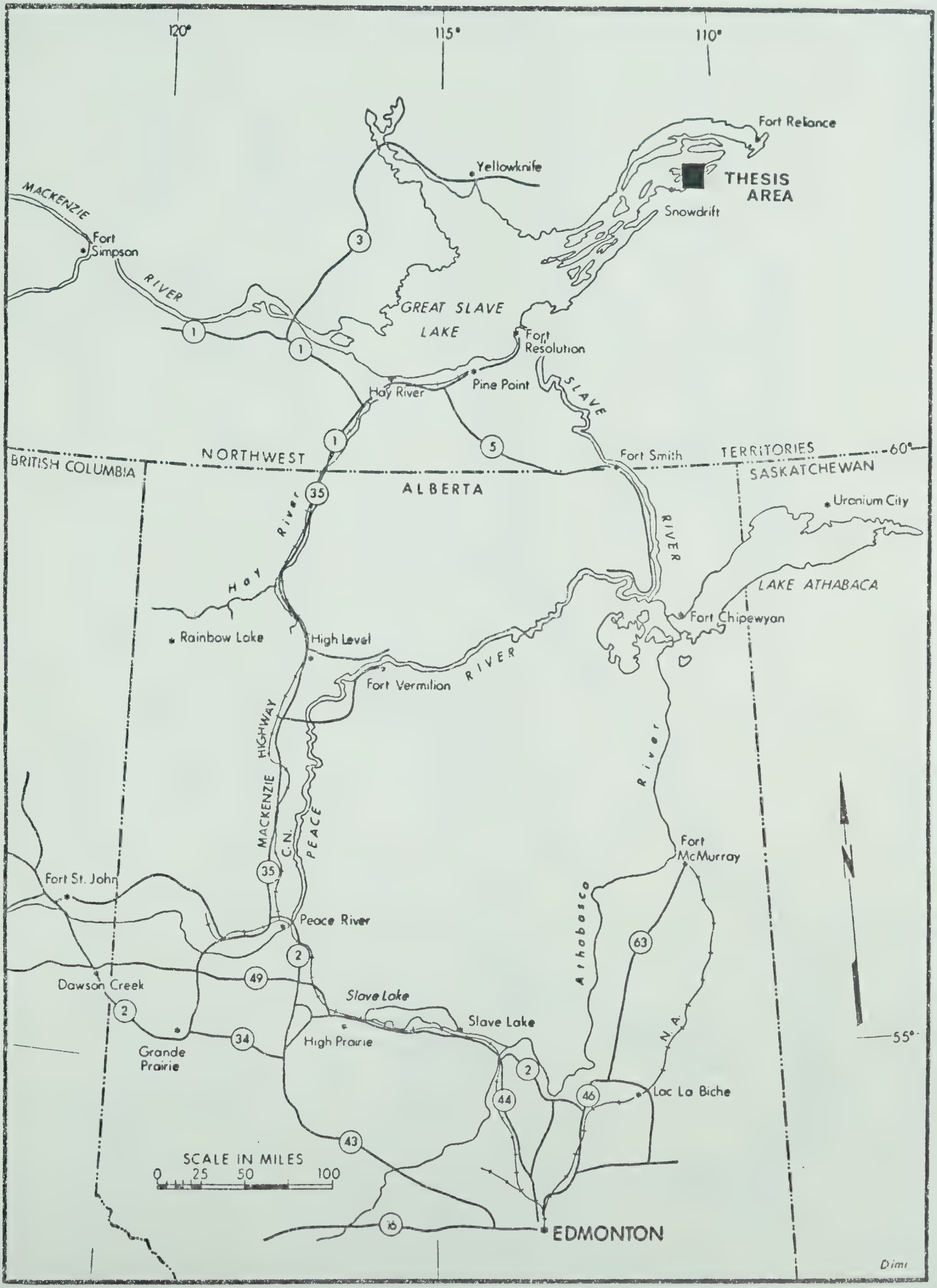


FIGURE 1: Location of study area.

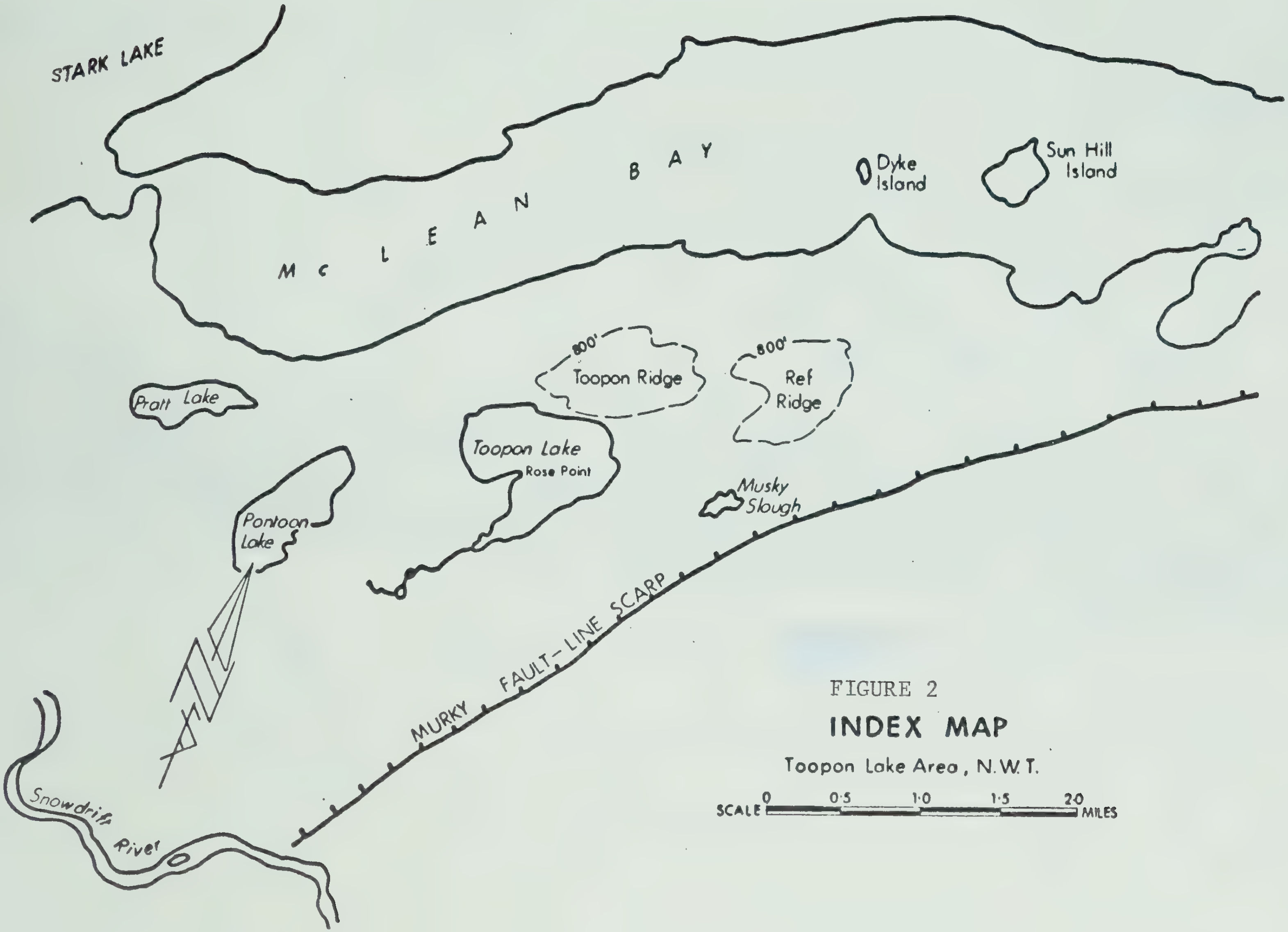


FIGURE 2

INDEX MAP

Toopon Lake Area, N.W.T.

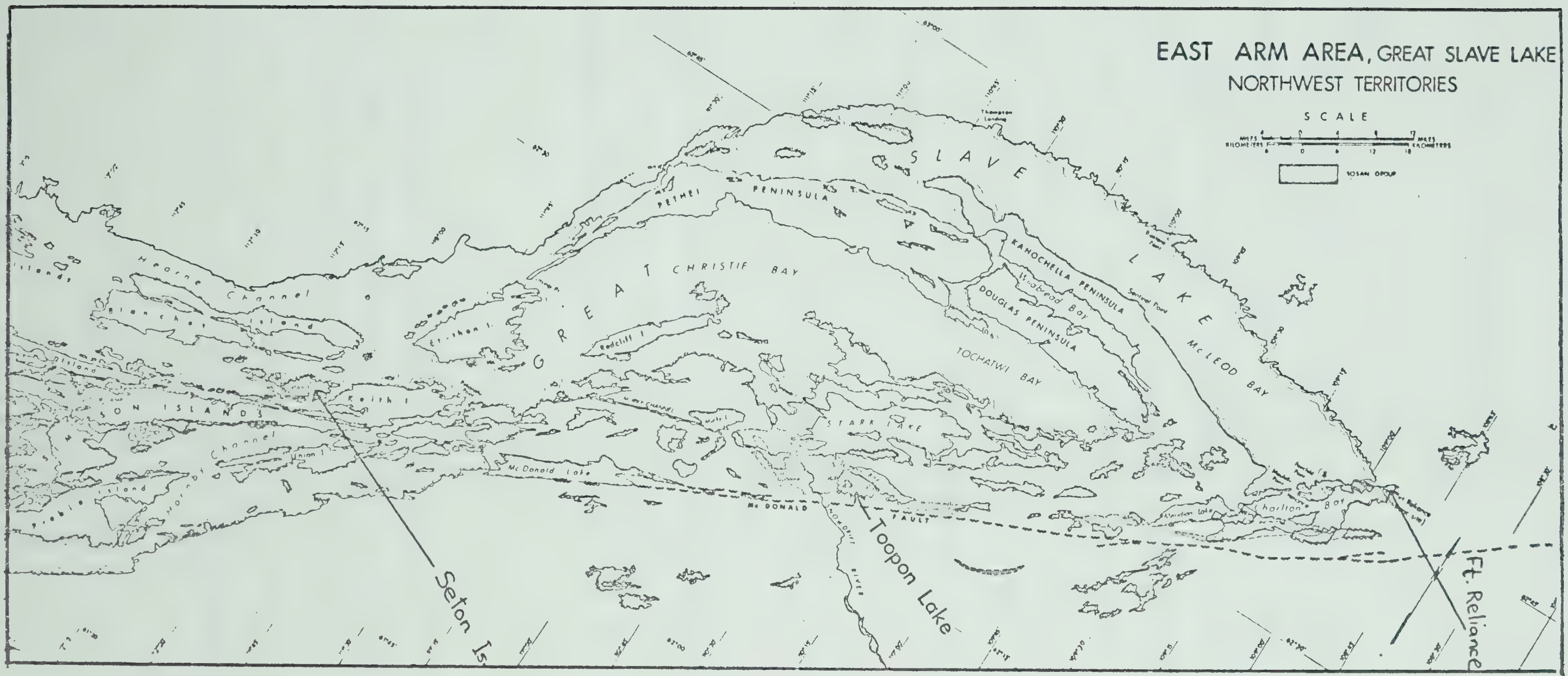


FIGURE 3: Map of the East Arm showing the location of Seton Island, Fort Reliance and Toopon Lake.

collected, is shown in Figure 3.

Physiography

The topography of the Toopon Lake map-area is typical of the East Arm structural basin. It is characterized by numerous, high isolated hills, long ridges and shallow lakes. The dominating physiographic feature is Toopon Lake which lies about 500 feet above sea level. This lake is surrounded by isolated hills and hogback ridges of which the most prominent is the NE-SW trending Murky Ridge which stands 1800 feet above sea level. It represents the outcrop of the resistant conglomerates of the Murky Formation which is bounded on both sides by fault-scarps. Drainage in the map-area is very poor. All the lakes are stagnant and often filled by extensive muskeg.

About 60% of the map-area is covered with surficial deposits and water. The outcrops occur on the prominent ridges and along the lake shores. The surficial cover is mainly undifferentiated drift and muskeg.

Previous Work

Geological investigations and mapping within the East Arm of Great Slave Lake have been conducted by officers of the Geological Survey of Canada since the beginning of this century.

The first account of the regional geology of the East Arm was given by BELL (1902). RUTHERFORD (1929) reported the

occurrence of algal stromatolites in samples of dolomite from the East Arm. In the same year, LAUSEN made the first attempt at systematic stratigraphy of the region.

In 1932, STOCKWELL published the first systematic geological mapping of the East Arm. His report, together with maps 377A and 378A (1936) formed the basis of all subsequent geological investigations in the region. Areas not covered by STOCKWELL's earlier survey were later described in maps and reports of BROWN (1950a, 1950b, 1950c) and WRIGHT (1951, 1952). BARNES (1951, 1952) mapped in somewhat greater detail, the Snowdrift and McLean Bay areas which include the area studied during this investigation.

The most recent and detailed report on the Aphebian rocks of the East Arm is that of HOFFMAN (1968). In this publication, HOFFMAN amplified the stratigraphic nomenclature of the area. HOFFMAN (1969) and HOFFMAN et al. (1970) attempted geographic and stratigraphic correlations between the Great Slave Supergroup and other Proterozoic rocks around the Slave Province.

Formations on the north limb of the synclinorium		Groups	Formations on the south limb of the synclinorium	
Stockwell (1936)	Hoffman (1968)	Hoffman (1968)	Hoffman (1968)	Stockwell (1936)
(eroded)	(eroded)	CHRISTIE BAY	Pearson	Pearson
			Portage Inlet	Tochatwi
	Tochatwi		Tochatwi	
Stark	Stark		Stark	Stark
Pethei	Hearne	PETHEI	Pekanatui Point	
	Wildbread		Blanchet	Kahochella
	Utsingi			
	Taltheilei		McLean	
	Douglas Peninsula		Douglas Peninsula	
Kahochella	Charlton Bay	KAHOCHELLA	Charlton Bay	
	McLeod Bay		McLeod Bay	
	Gibralter		Gibralter	
	Seton		Seton	
Sosan	Akaitcho River	SOSAN	Akaitcho River	Sosan
	Kluziai		Kluziai	
			Duhamel	
			Hornby Channel	

TABLE 1.

Comparison between the stratigraphic nomenclature for the 'Great Slave Group' used by Stockwell (1936) and that proposed by HOFFMAN (1968)

CHAPTER TWO

REGIONAL GEOLOGIC SETTING

The East Arm of Great Slave Lake is the site of a NE-SW trending Proterozoic fold belt in which has been preserved a 40,000 ft. ($\sim$ 12,190 m) thick sequence of sedimentary and volcanic rocks (HOFFMAN, 1969). This structural basin is about 180 miles ($\sim$ 290 km) long and 60 miles ($\sim$ 97 km) wide, and is regarded by STOCKWELL et al. (1970) as a Subprovince of the Churchill (structural) Province (Fig. 4).

Prominent NE-trending faults of the McDonald system transect all the Proterozoic rocks within the fold belt. HOFFMAN (1969), after his detailed stratigraphic study of the East Arm, considered the fold belt as an erosional remnant of a Proterozoic miogeosyncline. He made certain analogies between the Phanerozoic Appalachian miogeosyncline and the East Arm Aphebian sequence. However, in a subsequent account, HOFFMAN et al.(1970) regarded the East Arm fold belt as part of the so-called 'Coronation geosyncline' of Aphebian age.

Stratigraphy and Age

The Proterozoic rocks exposed within the East Arm of Great Slave Lake have previously been classified into seven groups (HOFFMAN, 1968, 1969), as shown in Table 2. Figure 5 presents a stratigraphic cross-section of the Proterozoic Formations from NE to SW of the region.

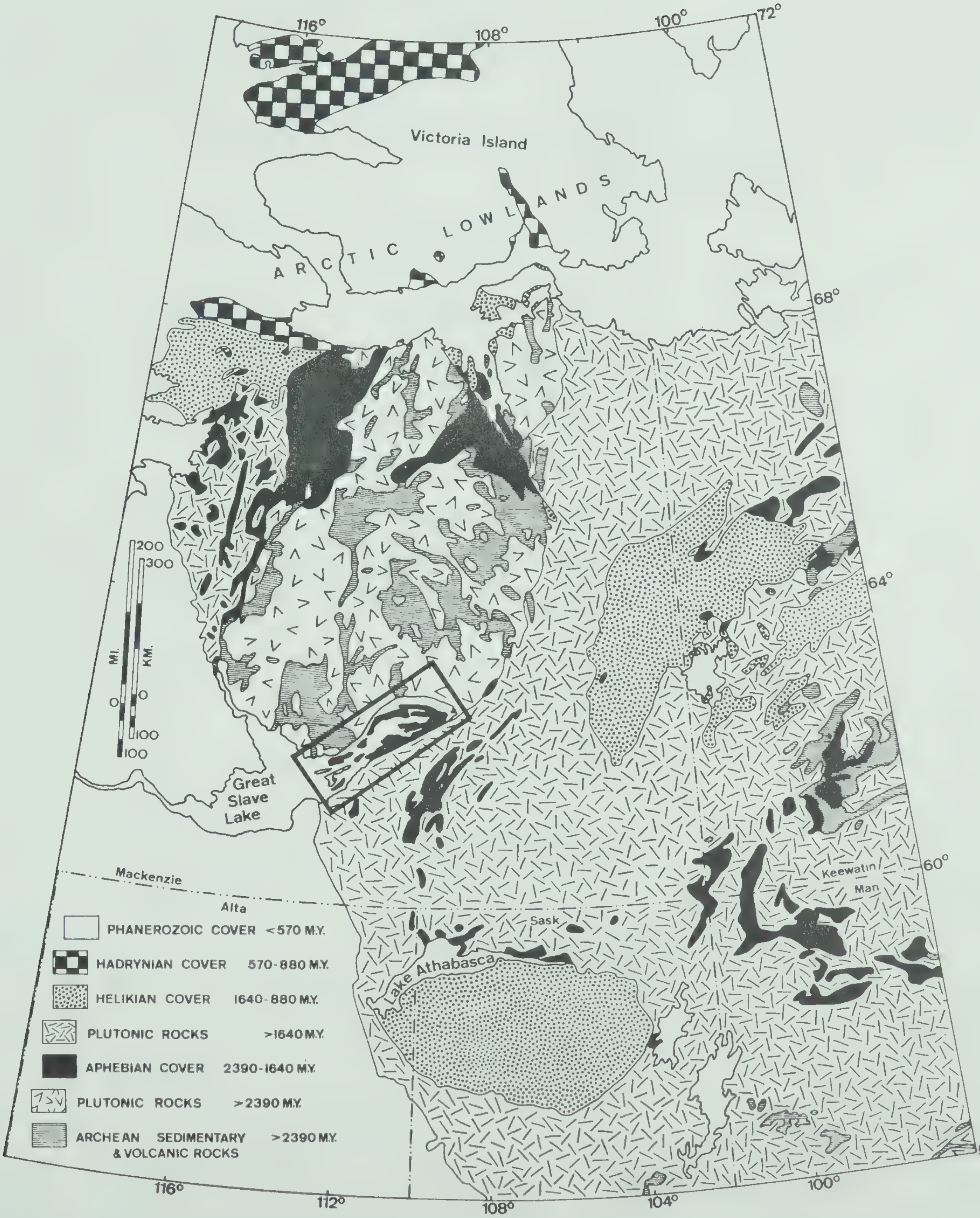


FIGURE 4: Regional geologic setting of the East Arm Subprovince, Great Slave Lake. (After HOFFMAN, 1969)

PROTEROZOIC	HELIKIAN	Diabase intrusives (1300 m.y.)	
	?(APHEBIAN)	Et-Then Group	
		..........UNCONFORMITY.............	
	APHEBIAN	Diorite and syenite laccoliths (1630-1845 m.y.)	
		Christie Bay Group)	
		Pethei Group)	Great Slave
		Kahochella Group)	Supergroup
		?Syenite dyke (2170-2200 m.y.)	
		Sosan Group)	
		..........UNCONFORMITY.............	
		Union Island Group	
		..........UNCONFORMITY.............	
		Wilson Island Group	
		..........UNCONFORMITY.............	
ARCHEAN		Granites and metamorphics (2370-2575 m.y.)	
		Yellowknife Group	

TABLE 2.

Simplified stratigraphic column for the Precambrian lithologies of the East Arm of Great Slave Lake.

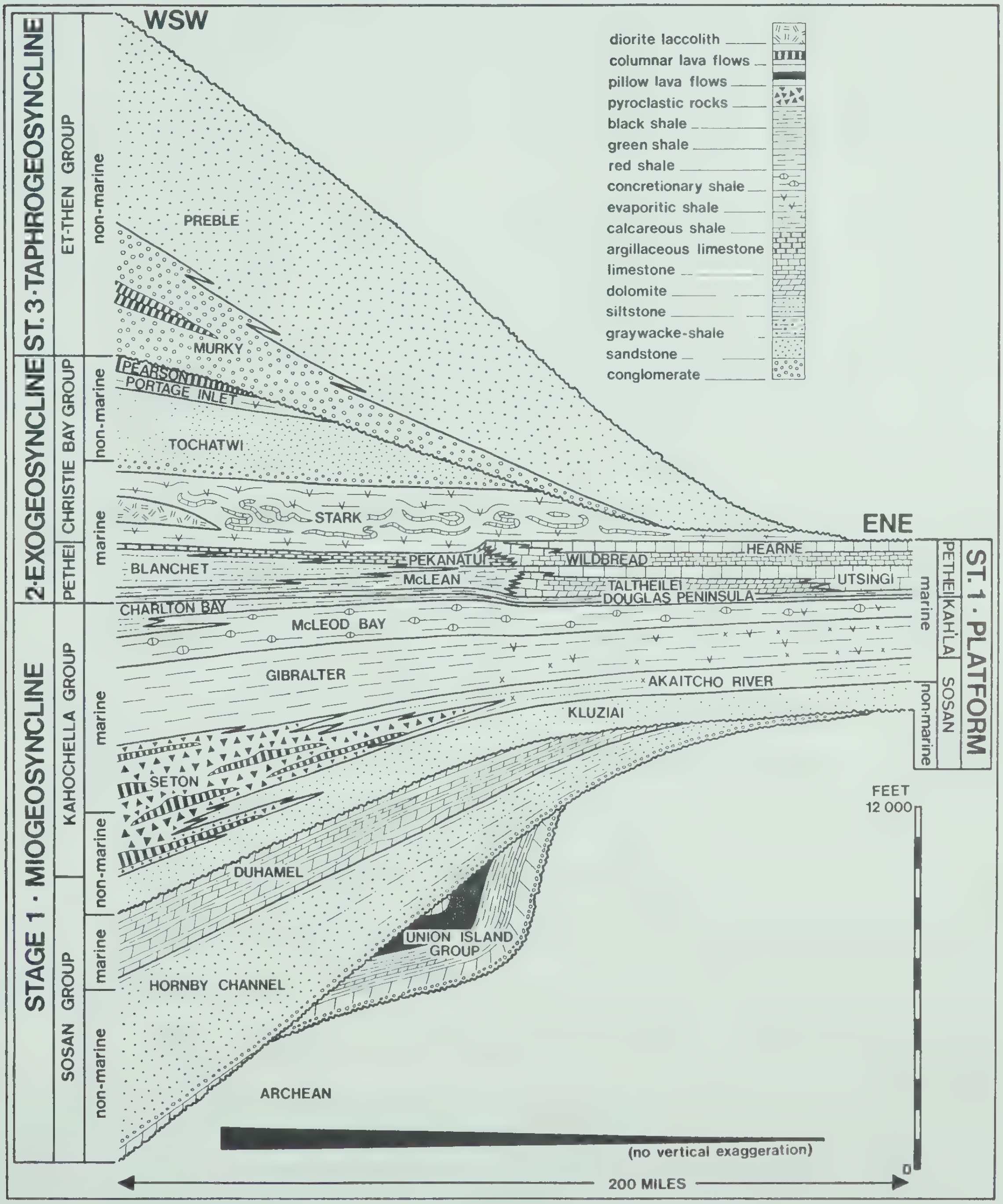


FIGURE 5: Stratigraphic cross-section of Proterozoic formations from the northeast to the southwest end of the East Arm Fold Belt. (After HOFFMAN, 1969)

The Wilson Island and Union Island Groups comprise slates, dolomite, quartzite and lavas, deposited unconformably upon Archean granites and metamorphics. These two Groups exhibit a complex tectonic and stratigraphic history that differentiates them from the overlying younger rocks. They most probably represent relicts after a post-Kenoran, pre-Hudsonian structural event.

The Sosan Group is the basal member of the Great Slave Supergroup and lies unconformably upon Archean basement rocks and the Proterozoic Wilson Island and Union Island Groups. The Sosan Group has been subdivided into four formations. The basal Hornby Channel Formation consists dominantly of coarse fluvioclastics and rare volcaniclastic and carbonate rocks. A 2200 m.y. old syenite dyke probably intrudes the Formation on North Simpson Island (WALKER, 1971; BURWASH and BAADSGAARD, 1962). The Duhamel Formation which overlies the Hornby Channel Formation comprises a cyclic dolomite-siltstone or sandstone sequence which was deposited on a slowly subsiding tidal platform. Fluvial sandstones of the Kluziai Formation pass upwards into deltaic or marine siltstones, sandstone and shale of the Akaitcho River Formation.

The volcanic-marine shale succession of the Kahochella Group conformably overlies the Sosan Group. Above the Kahochella Group is the carbonate-greywacke facies of the Pethei Group, which is overlain by a thick sequence of red beds and basalt flows belonging to the Christie Bay Group. HOFFMAN <u>et al.</u>(1970)

consider the greywacke of the Pethei Group and the lithic clastics of the Christie Bay Group as the synorogenic phase of sedimentation in the 'Coronation orthogeosyncline'.

All the afore-described rocks have been intruded by quartz diorite laccoliths dated by biotite K-Ar method at 1785 m.y.,1795 m.y. and 1845 m.y.(HOFFMAN,1969) except the three uppermost formations.

The Et-then Group represents a post-orogenic molasse facies deposited unconformably upon folded rocks of the Great Slave Supergroup. This Group consists of two formations; the basal Murky Formation comprises fanglomerates, red beds and basalt flows, while the overlying Preble Formation consists predominantly of sandstones.

Diabase dykes of the MacKenzie swarm dated as 1300 m.y. (FAHRIG and WANLESS, 1963) transect the Et-then Group and the older rocks.

HOFFMAN et al. (1970) stratigraphically correlated the Great Slave Supergroup with the Epworth and Goulbourn Groups of the Bear Province. FRASER et al. (1970) consider the Et-then Group as a stratigraphic equivalent of the tephrogeosynclinal, red-bed sequences of the Martin and Athabasca Formations of Northern Saskatchewan and the Northwest Territories.

Major Structures

The East Arm of Great Slave Lake is the site of a NE-SW trending asymmetric synclinorium which is upturned at both extremities. The NW limb of the fold dips gently (less than 20°),

while the SE limb is tightly folded and faulted, exhibiting much steeper dips and inversion in certain places.

Many anticlines and synclines, whose axes parallel that of the synclinorium, characterize the southern sector of the region. These secondary folds, in many places are microcosms of the East Arm fold belt itself. It is believed that the folding in the East Arm may be related to the uplift and deformation of the Aphebian rocks in the Coronation geosyncline during the Hudsonian orogeny (STOCKWELL et al., 1970).

Prominent NE-trending faults of the McDonald Fault System transect the rocks of the region. HOFFMAN (1969) considers these faults as part of an asymmetric Precambrian graben system which parallels the axial trace of the synclinorium. The McDonald Fault itself, forms the SE boundary of this graben. REINHARDT (1969a, 1969b) recognises two phases of movement on these faults (Fig. 6). The first phase consisted primarily of dextral transcurrent movement with associated mylonitization, brecciation and recrystallization of the Archean basement complex. The second phase which is probably more significant, produced vertical displacements of the Proterozoic rocks along the old pre-existing faults.

Another younger system of NW or NNW trending faults was noted by REINHARDT (1969a, 1969b) in the SW of the East Arm.

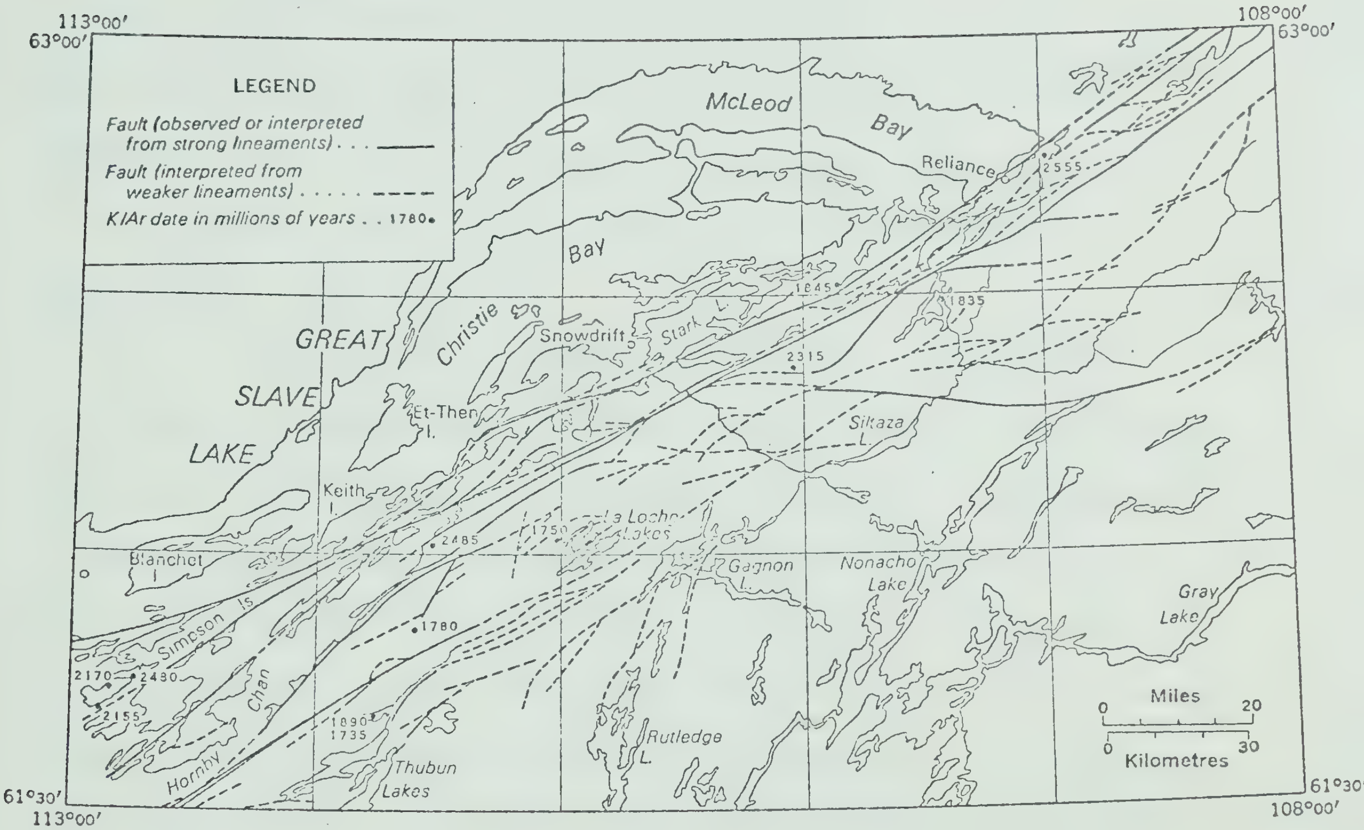


FIGURE 6: The McDonald Fault System, East Arm of Great Slave Lake. (After REINHARDT, 1969)

CHAPTER THREE

STRATIGRAPHY AND SEDIMENTATION

Introduction

The rocks exposed within the Toopon Lake map-area are predominantly sedimentary and volcanic rocks of the Sosan and Kahochella Groups (Fig. 7). The rocks of the Et-then Group which crop out just south of the map-area, were mapped on a reconnaissance basis, but no stratigraphic descriptions are presented in this thesis.

Field mapping in the study area was carried out on various scales and detail, for the purpose of this investigation and for the use of Vestor Explorations Ltd. The stratigraphic nomenclature utlilized in stratigraphic descriptions and geo-mapping, is that of HOFFMAN (1968), Table 1. Although HOFFMAN established new lithostratigraphic units in the East Arm, he did not produce an accompanying map. It was, however, observed that the Formations he established, possessed well-defined contacts and were easily mappable. A large-scale geologic map of the study-area is presented in Figure 8.

The aim of this chapter is to present an account of the stratigraphy, petrography, paleocurrents and paleoenvironment of the uranium-bearing formation (Kluziai Formation) and related rocks, with the hope of: (1) elucidating any relationships between radioactive occurrences and sedimentary texture,

TABLE 3

TABLE OF FORMATIONS,TOOPON LAKE AREA

EON	ERA	SUPER-GROUP	GROUP	FORMATION	MEMBER	LITHOLOGY
PROTEROZOIC	CENOZOIC (Pleist-ocene & Recent)					Glacial deposits; lacustrine and fluvial gravel,sand and clay
	- U N C O N F O R M I T Y -					
	PALEO-HELIKIAN	1295 m.y. MacKenzie Swarm				Diabase dykes
		I N T R U S I V E C O N T A C T				
	APHEBIAN		Et-then Group	Murky Formation 300'-2000'		Conglomerate,polymitic; conglomeratic arkose; siltstone;shale and amygdaloidal basalt
		- U N C O N F O R M I T Y -				
		GREAT SLAVE SUPERGROUP	Kaho-chella Group	Gibralter Formation 100'+		Shale,red and green,thinly laminated; calcareous concretions
				Seton Formation 0-800'		Tuffs,spilitic and quartz-keratophyric, reworked and primary; agglomerate; tuff-breccia; tuffisite; volcanic sandstone; spilitic lava flow
			Sosan Group	Akaitcho River Formation 30'-1000'	Glauconitic Siltstone Member	Siltstone,red,glauconitic,flaggy; minor green glauconitic siltstone
					White Orthoquartz-zite Member	Sandstone,white,orthoquartzitic,non-glauconitic; minor purple sandstone
				Kluziai Formation 200'-1200'	Upper Member	Sandstone,calcareous,micaceous,flaggy; minor quartz-pebble conglomerate; ubi-quitous cross-bedding
					Middle Member	Sandstone,orthoquartzitic to subarkosic, silica cement; minor intraformational conglomerate
					Lower Member	Sandstone,pebbly,limonitic; minor lenses of dolomite;silica plus carbonate cement
				Duhamel Formation 150'+		Dolomite,purple to brown,stromatolitic; sandy dolomite,hematitic; siltstone, purple; calcareous shale;jasper beds

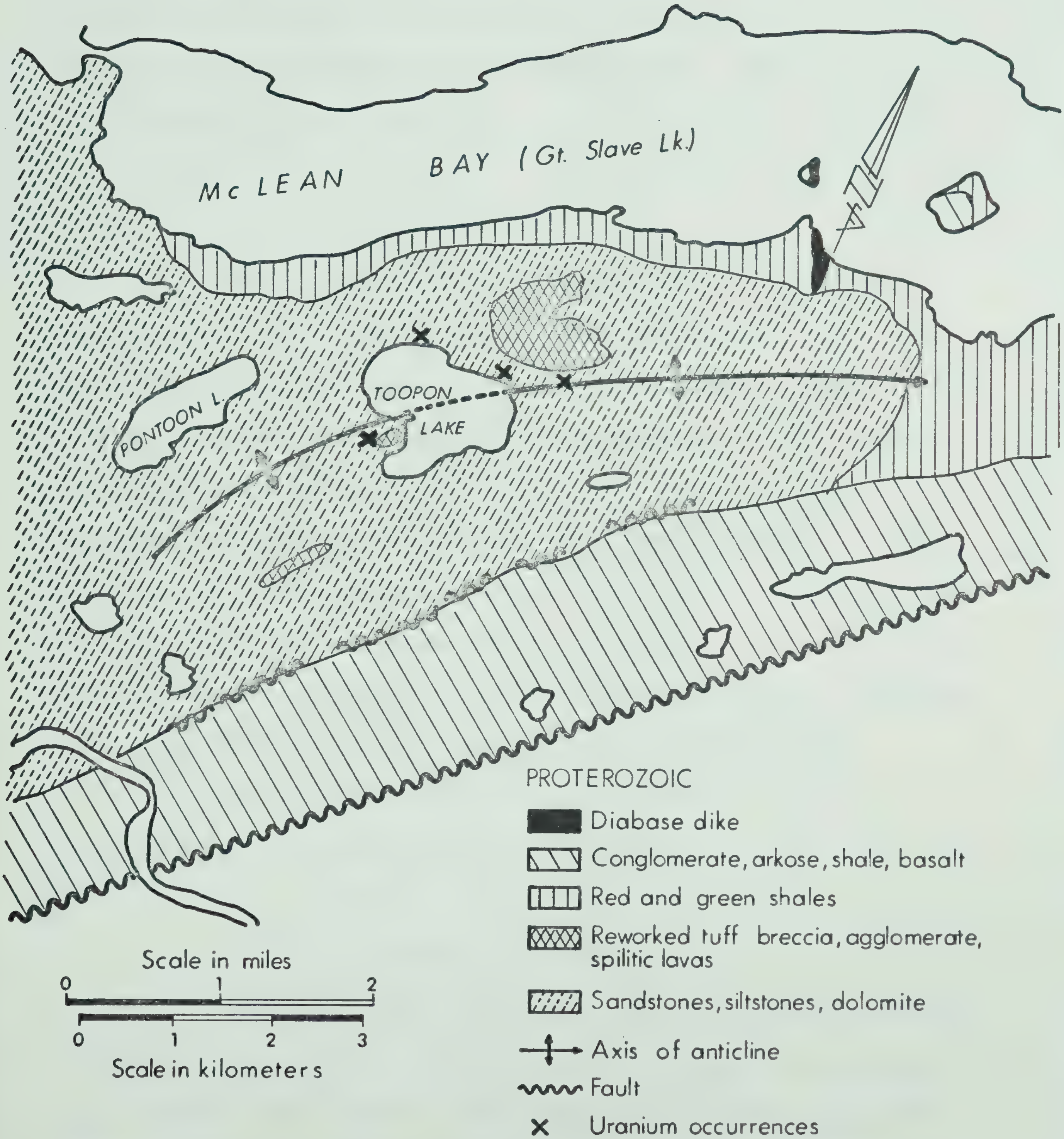


FIGURE 7 : Generalized Geologic Map. Toopon Lake Area, N.W.T.

structures or mineralogic composition, (2) determining the environment of deposition of the ore-bearing rocks, and (3) subdividing into members, where necessary and feasible, the recently established lithostratigraphic units (HOFFMAN, 1968), which are well-preserved in the map-area.

Sosan Group

The Sosan Group is the lowest Group in the Great Slave Supergroup. HOFFMAN (1968, 1969) subdivided it into four distinct formations, named in ascending order: the Hornby Channel, Duhamel, Kluziai and Akaitcho River Formations. Figure 9 shows the supposed stratigraphic relationships within the Lower Aphebian rocks of the Great Slave Supergroup. The Seton Formation, which in the SW sector of the East Arm is laterally equivalent to the Akaitcho River Formation and the upper beds of the Kluziai Formation, is not included in the Sosan Group by HOFFMAN, but classified as the basal unit of the Kahochella Group.

In the map-area, all the formations of the Sosan Group, except the Hornby Channel are exposed.

Duhamel Formation

The name Duhamel Formation was first used by HOFFMAN (1968) to designate the cyclic sequence of dolomites, sandstone and siltstone that overlies the conglomeratic sandstones of the Hornby Channel Formation. The type section is located north of Lac Duhamel, about 15 km west of the study area. HOFFMAN (ibid.)

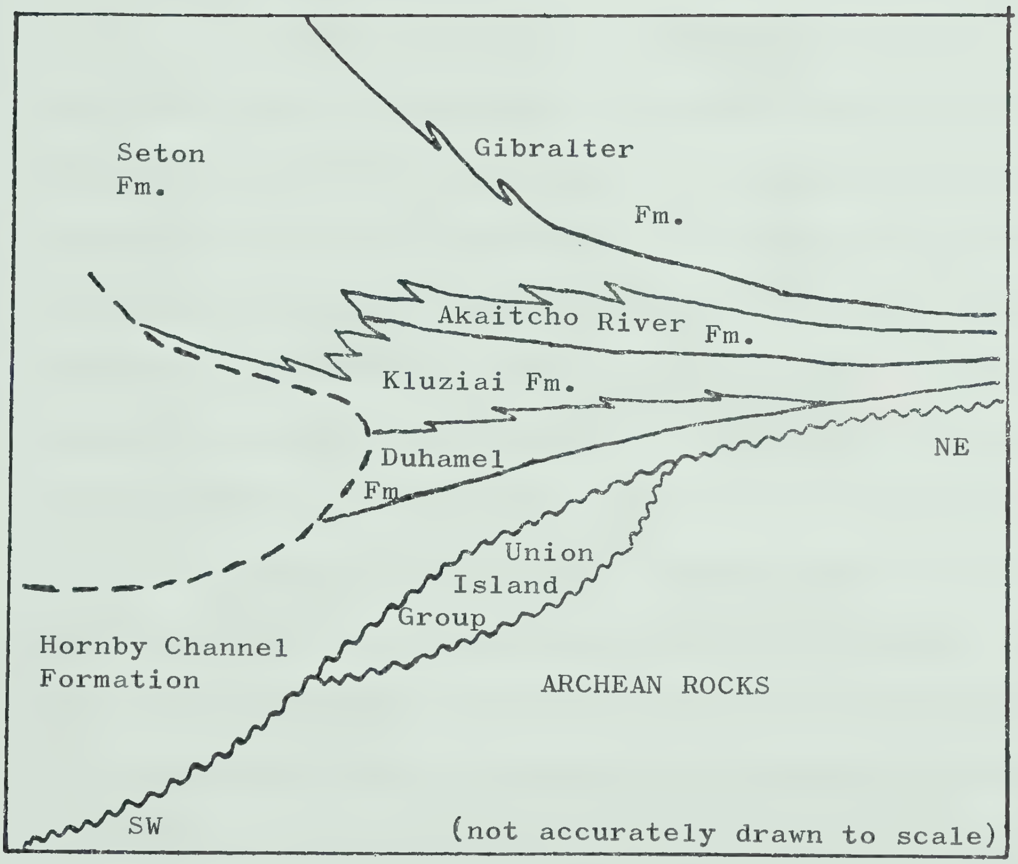


FIGURE 9: Diagrammatic cross-section showing the supposed stratigraphic relations within the Lower Aphebian rocks of the Lower Great Slave Supergroup. (Modified after HOFFMAN, 1968)

suggests that the Duhamel Formation was deposited in a tidal-flat environment in which the interbedded terrigenous material was transported into the shore environment by ephemeral river deltas and reworked by wave action prior to deposition. HOFFMAN further notes that the formation is of very restricted distribution, with all known exposures occurring within a 20 km radius of the study area.

In the map-area, the Duhamel Formation is about 150 ft. thick and comprises dolomites, siltstones and calcareous shale. Exposures occur only in the area SW of Toopon Lake, north of Murky Ridge scarp (Fig. 8). The base of the Formation is not exposed. The upper contact is drawn at the point where the brown sandy dolomite passes into a massive orthoquartzitic sandstone of the Kluziai Formation. Four lithologic units are distinguished within this Formation:

(i) Brown to Grey Dolomite - This lithologic unit is grey to purple in color and weathers brown. It constitutes more than 50% of the exposures and is interbedded with the other lithologies. It is massive to thinly laminated, and compact to coarsely crystalline.

In thin section, the dolomite is composed of a mosaic of very fine-grained dolomite anhedra. Replacement and vein-like patches of coarsely crystalline and twinned dolomite rhombs are common. The grain size of the coarse dolomite crystals range from 0.5 mm. to 1.5 mm. Secondary quartz fills few interstices.

Certain concentric structures which are definitely

stromatolitic were observed in the dolomite.

(ii) Sandy Dolomite -A few beds of arenaceous dolomite occur in the upper part of the Formation. This lithology is also brown-weathering,but gritty or granular to the touch. Bedding is thick to medium,and no algal structures were observed.

Microscopic examination shows that this dolomite consists of scattered, subrounded to rounded grains of sand- to silt-sized quartz and feldspar, set in a groundmass of fine-grained dolomite. The estimated modal percentages of the mineral constituents are:- quartz 15-20% and dolomite 80-85%. Thin beds of red jasper and specular hematite occur within this lithologic unit.

(iii) Siltstone - Purple or red-brown siltstone occurs in the lower part of the sequence. This unit is usually thin-bedded and somewhat friable. Mudcracks and ripple-marks were observed in some of the loose slabs, although none were seen on outcrops. The major mineral components are silt-sized quartz, which constitutes about 75% of the mode, muscovite plus K-feldspar form 10% of the rock. The groundmass is hematite and dolomite.

(iv) Calcareous Shale - This lithology constitutes about 20% of the rocks exposed in this formation. This unit is finely-laminated and greyish-white in color. The carbonate content of the rock ranges from 10-30%, while the predominant argillaceous component consists of clay minerals and fine-grained micas. Structural incompetence has resulted in contortion and drag-

folding in this lithology.

Kluziai Formation

Introduction

HOFFMAN (1968) applied the name Kluziai Formation to a uniform sequence of "cross-bedded, fine-grained, even-textured, pink to grey sandstone" which conformably or paraconformably overlies the dolomites of the Duhamel Formation in the type section. HOFFMAN (op. cit.) also notes that the Kluziai Formation is present throughout the East Arm, except in the extreme southwest of the region where the Formation has been removed by erosion. The Kluziai Formation represents the second sequence of sandstones within the Sosan Group.

The nature of the Duhamel-Kluziai contact may seem controversial. HOFFMAN (1968, 1969) suggests that this contact is paraconformable. He based his conclusion on the facts that: in the type section, the uppermost dolomite beds are fractured and silicified, although the contact was not exposed. Furthermore, HOFFMAN (op. cit.) observed that the fluvial Kluziai Formation "progressively overlies older beds from south to north", and this feature HOFFMAN considers as "overstepping, common in basal transgressive sequences".

Based upon the author's observations in the study area and other parts of the East Arm, it is herein suggested that the contact between the Kluziai and Duhamel Formations may be conformable. The existence of paraconformities or what

KRUMBEIN and SLOSS (1963) consider as 'obscure' unconformities are difficult to prove or substantiate, especially when the crucial paleontological evidence is lacking in Precambrian rocks (DUNBAR and RODGERS, 1957).

The fracturing and silification of the dolomite have only been observed in one stratigraphic section, and these features can possibly be associated with local deformation. Most of the rocks exposed in the map-area are usually silicified along faults or fractures(OLADE,1971a).

The lithologic change from dolomite of the Duhamel Formation to orthoquartzite in the Kluziai Formation is not abrupt. Arenaceous dolomite characterizes the upper part of the Duhamel Formation (HOFFMAN, 1968), while the basal unit of the Kluziai Formation contains brown-weathering dolomite lenses. Also, HOFFMAN (1968, 1969) noted that 20% of the Duhamel Formation is composed of interbedded orthoquartzite, similar to the Kluziai Formation, while 40% of the dolomites are arenaceous. Thus, the change in lithology between the two Formations is neither abrupt nor does it necessarily indicate a break in sedimentation.

The fact that the Kluziai Formation "oversteps" older Formations from south to north may be differently interpreted. The regional paleoslope during the deposition of the Sosan Group was NE-SW, and throughout the NE of the region, the sediments constitute a thin veneer on the Archean basement. Thus, the northern part of the basin was possibly a paleotopographic

high on which there was no major deposition until Kluziai times. Based upon the aforementioned considerations, there are no unequivocal reasons to support a Duhamel-Kluziai unconformity as suggested by HOFFMAN (1968).

In the Toopon Lake map-area, the Kluziai Formation is about 1200 ft. thick and comprises subarkosic to orthoquartzitic sandstones and conglomerates. It is the host to uranium mineralization in the area.

The lower contact of the Formation is drawn at the base of the lowest sandstone bed. The Akaitcho River Formation conformably overlies the Kluziai Formation. In the study-area extensive outcrops of the Kluziai Formation occur along the lake shore, and further east and northwest of the Lake, towards McLean Bay (Fig. 8).

The Kluziai Formation is subdivided into three distinct members, which are mappable and can be traced throughout the central part of the region. Brief descriptions of the members are presented in Table 4.

Lower Member

The Lower Member constitutes the basal unit of the Kluziai Formation. It consists mainly of silicified and pebbly sandstones with lenses of dolomite. This Member is not commonly exposed, and has only been observed in two localities within the map-area. Beyond the northeast shore of Toopon Lake, the Lower Member is exposed along a cliff-face due to upfaulting against

TABLE 4

TABLE OF MEMBERS

KLUZIAI FORMATION

Members	Lithologic Description	Approximate Thickness
Upper Member	Buff to light brown, fine-to medium-grained, thin- to medium-bedded, micaceous (5%), moderately sorted, friable, calcareous sandstone. Intercalated beds of quartz-pebble conglomerate. Ubiquitous festoon cross-bedding. Minor green shale partings and shale-pebble conglomerate.	200-300'
Middle Member	Pink to buff, medium-grained, medium- to thick- bedded or massive, well sorted, silicified, orthoquartzitic to rarely subarkosic sandstone. Ripple-marks and few festoon and planar cross-beds. Minor intraformational conglomerate and breccia.	600-700'
Lower Member	Buff to pale-brown, fine-to medium-grained, thin- to medium-bedded, limonitic (1-5%), pebbly sandstone. Carbonate and silica cement. Intercalated lenses of dolomite and sandy dolomite. Sparse cross-bedding. Sandstone becomes massive and highly silicified near base.	150'+

younger rocks. The base is however, not exposed in this section. Southwest of the lake, an outcrop of 30-40 ft. thick, pink orthoquartzite with a few dolomite lenses, directly overlies the Duhamel Formation. This exposure is considered as the lower part of this Member because of its stratigraphic position and similarity to the rocks exposed at the base of the Lower Member in the other locality northeast of Toopon Lake. -

The Lower Member is subdivided into an upper part and a lower part. The lower part consists of massive orthoquartzitic sandstone, while the upper part comprises a sequence of thin- to medium-bedded, pebbly calcareous sandstone.

(i) Buff Orthoquartzitic Sandstone - This lithologic unit is buff to light-pink in color and occurs in the lower part of the Member. It is thick-bedded to massive and commonly, highly silicified. In thin section, it is fine- to medium-grained and consists predominantly of clastic quartz and few grains of feldspar, set in a groundmass of silica and sericite. The grains are subrounded and sorting is good to moderate. A few lenses of brown-weathering dolomite occur within this unit.

(ii) Pebbly Calcareous Sandstone - This sandstone is buff to pale-brown, calcareous and limonitic. Pebbles of quartz are irregularly distributed within the unit. Bedding is thin- to medium, and this feature accentuates the friability of this lithology. Microscopic examination shows that the rock is medium- to fine-grained, consisting of subrounded to subangular grains of quartz, microcline, plagioclase feldspar, orthoclase

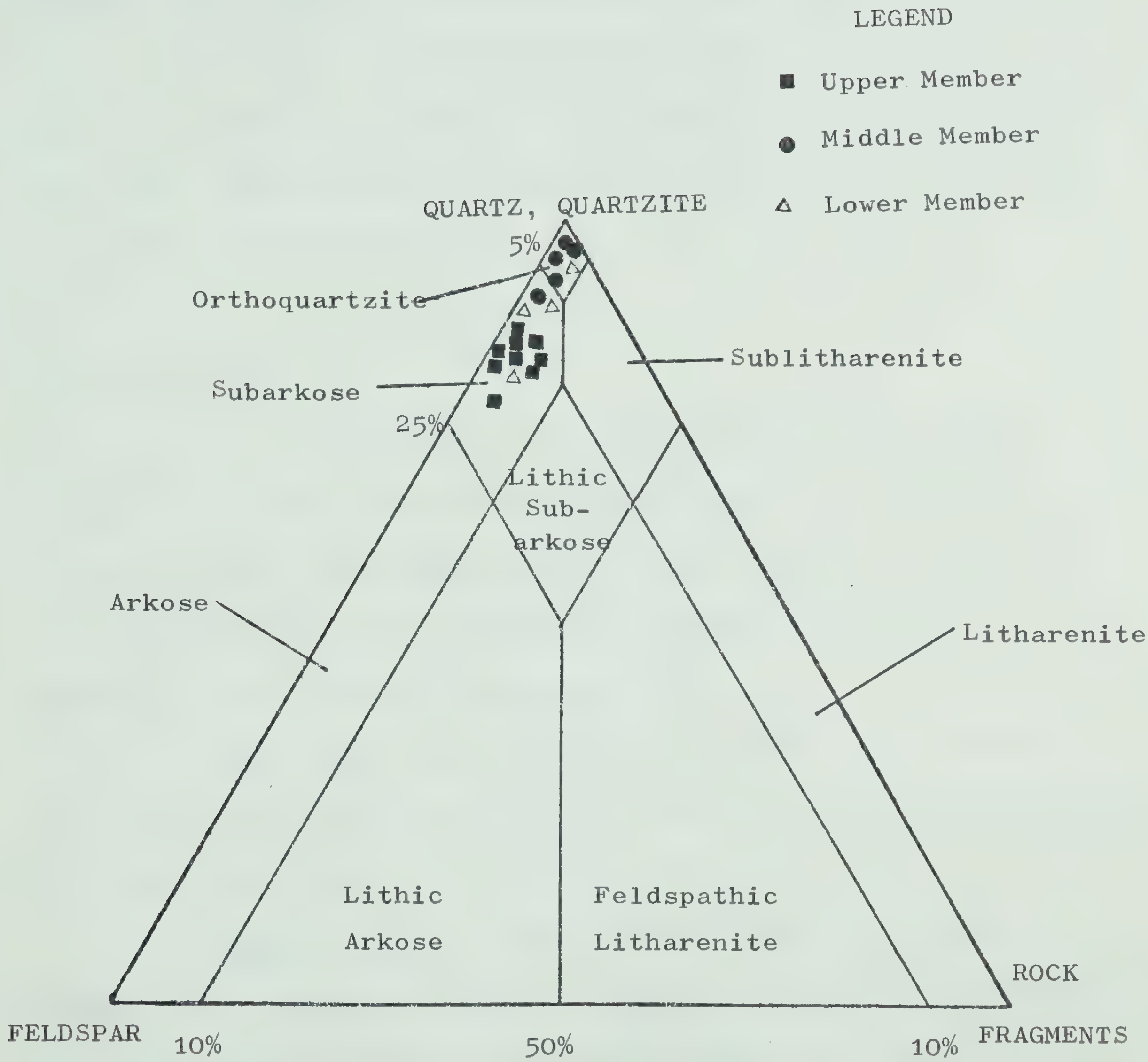


FIGURE 10: Petrographic classification of Kluziai sandstones. (After McBRIDE 1965)

and muscovite, set in a matrix of carbonate and silica. The pebbles range in size from 2-3 mm, while the size of the other grains average 0.5 mm. Quartz constitutes about 70% of the rock, feldspar 12%, limonite and muscovite 3%, and carbonate 15%.

Horizons of brown-weathering dolomite and sandy dolomite, usually less than 0.5 ft. thick are intercalated within this unit. Red hematite staining sometimes imparts a pink or red color to this lithology.

Middle Member

The Middle Member is about 600 ft. thick, and is exposed along the north and southwest shores of Toopon Lake. It overlies the Lower Member and its base is drawn at the level in which the thin-bedded calcareous sandstone passes into a strongly silica-cemented orthoquartzite.

This Member consists mainly of lenticular, medium- to thick-bedded orthoquartzite and intraformational conglomerate. It is divisible into two lithologic units.

(i) Orthoquartzite - This lithology is buff to pink in color. It is medium- to thick-bedded with a few shale partings. The high degree of silica cementation makes this rock very difficult to break. In thin section (Plate 2-A), the orthoquartzite is even-textured, medium-grained and consists of rounded to sub-rounded, closely-packed grains of quartz and feldspar, cemented by secondary silica, which fills interstices and occurs as overgrowths. The orthoquartzite is well-sorted and

can be regarded as texturally mature.

Clastic quartz constitutes about 90% of the rock. It occurs as subrounded to rounded monocrystalline grains that exhibit straight to slightly undulose extinction. Grain sizes vary from 0.35-0.5 mm. Serrated grain boundaries are present, as a result of small embayments of sericite along clastic grain boundaries. Minute inclusions of opaque minerals occur within some of the quartz grains. Authigenic quartz, in the form of void fillings and overgrowths is present in the rock. Microcrystalline quartz fragments occur rarely.

Feldspar makes up 5-8% of the rock. A few beds that are more feldspathic contain about 10% feldspar. Untwinned orthoclase and "cross-hatched" microcline form rounded grains usually smaller in size than the detrital quartz. Many of the potash feldspar grains show incipient or complete alteration to mesocrystalline white mica. Plagioclase feldspar is not common, and the few small grains observed, show indistinct lamellar twinning and incipient alteration.

Minor accessory minerals include rounded zircon, monazite, barite and magnetite. In a few places, red secondary hematite staining imparts a deep pink color to the rock.

The matrix of the orthoquartzite constitutes 1-2%, and consists mainly of secondary quartz and recrystallized sericite.

(ii) Intraformational Conglomerate - This boulder conglomerate occurs as sporadic outcrops within the orthoquartzite

in the upper part of the Middle Member. Most of these outcrops are lenticular, and pass on all sides into the orthoquartzite. The boulders are angular to subrounded and similar in lithologic composition to the rocks of the overlying Upper Member. The fragments are friable, calcareous- and micaceous- sandstones which commonly retain their initial bedding features. The groundmass of the conglomerate which constitutes less than 10% of the rock is a fine-grained sandstone. Cementation and sorting is poor and the rock lacks coherence.

The angular nature of most of the fragments indicates little or no transportation from the source area. The similarity in composition between the boulders and the overlying Upper Member suggests that the conglomerate was formed after the deposition and partial consolidation of the enclosing unit and the micaceous sandstone of the Upper Member. This conglomerate is most probably a product of bank caving and erosion, commonly associated with the rapid channel-wandering of anabranches in braided streams or undercutting and caving of banks in meandering streams.

Upper Member

This Member consists mainly of friable, micaceous sandstone and conglomerates. Bedding is thin to medium and distinctly lenticular (Plate 1-A). Crumbly, pale-green, shale partings occur along many bedding planes.

The Upper Member is widely- and well-exposed within

the map-area, and the type section is located near the north shore of Toopon Lake. The lower contact of this Member is drawn at the level where the massive, highly silicified orthoquartzite of the Middle Member passes into a friable, calcareous, thin-bedded, micaceous sandstone. The red siltstone of the Akaitcho River Formation conformably overlies this Member and the contact is placed at the base of the lowest bed of red siltstone. This Member is composed of three lithologies.

(i) Friable Micaceous Subarkose - Characteristic of this lithologic unit is the presence of detrital muscovite flakes commonly aligned parallel to bedding. Also, this rock is crumbly due to the calcareous cement, and the thin bedding (Plate 1-A). Sorting is moderate.

The clastic component of the sandstone consists of about 80% quartz, 15% feldspar and 5% muscovite. The quartz grains are monocrystalline, subrounded and range in size from 0.2 to 0.45 mm. Orthoclase, microcline and plagioclase (oligoclase?), in that order of abundance, occur in the rock. Muscovite flakes with an average size of 0.6 mm. occur between the other clastic grains. Accessory minerals include magnetite and zircon.

The matrix of the micaceous subarkose is carbonate, and it constitutes about 15% of the modal composition.

(ii) Quartz-Pebble Conglomerate - Thin lenticular beds of quartz-pebble conglomerate form intercalates within the micaceous subarkose.

In thin section (Plate 2-B), this conglomerate is poorly sorted and consists of well-rounded, monocrystalline and polycrystalline pebbles of quartz, microcline, muscovite and recrystallized chert, set in a carbonate-cemented, fine clastic matrix. The grain size of the pebbles ranges from 2.5 mm to 4 mm. The polycrystalline grains contain two to six composite grains which exhibit straight to slightly undulose extinction. Many of the grains contain opaque and mineral inclusions.

The groundmass of the conglomerate consists of poorly sorted grains of sand-sized quartz and feldspar, cemented by carbonate.

(iii) Shale-Pebble Conglomerate - This lithologic unit crops out in a few localities, northwest of Toopon Lake. It consists mainly of green, sericitic- and red, hematitic- fragments of shale, and a few hematized, sandstone fragments, set in a groundmass of calcareous sandstone. These fragments are up to 10 cms. in size. The conglomerate merges on all sides into the micaceous subarkose.

Sedimentary Structures

Cross-bedding is the dominant, primary sedimentary structure in the Kluziai Formation. In describing this feature, the terminology of McKEE and WEIR (1953) is followed.

Festoon cross-bedding is ubiquitous in the Upper Member. It commonly exhibits a curved, lower bounding surface that is erosional. The festoon cross-beds are medium- to

large-scale, and commonly occur as cosets lying on minutely scoured surfaces, and overlain by thin lenses of quartz-pebble conglomerate (Fig. 11B). The silica-cemented sandstone of the Middle Member exhibits fewer cross-beds (Plate 1-B) than the Upper Member. However, planar cross-bedding was observed in the Middle Member. In the Lower Member, festoon cross-bedding is very sparse, and this serves a useful purpose of differentiating the Lower Member from the Upper Member. Deformed cross-bedding is quite common in the Middle Member (Fig. 11A).

Ripple marks are relatively scarce in the Kluziai Formation. The few ripple marks observed in situ and in loose slabs (Plate 1-C) are somewhat symmetrical and may represent oscillation ripple marks.

Minor scour-and-fill structures occur in the Upper Member. Mud cracks were observed in a few of the shale partings.

Antidunes and other structures characteristic of upper flow regime do not occur in the Kluziai Formation.

Paleocurrents

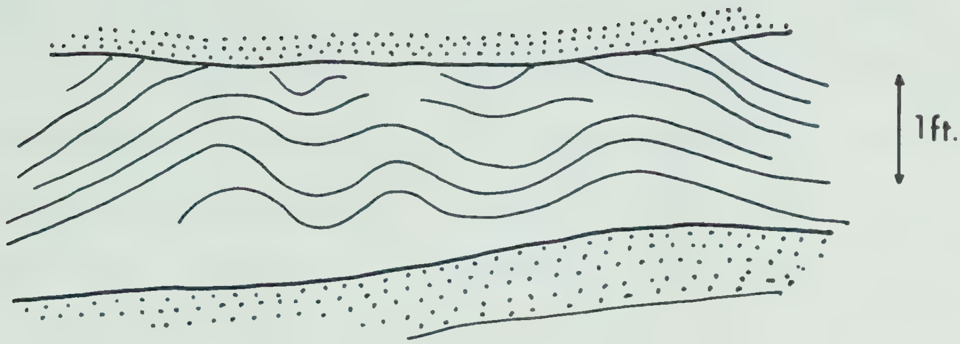
The application of paleocurrent studies to the determination of provenance, paleoslope and paleoenvironment has been well discussed in recent geologic literature (POTTER and SIEVER, 1956; POTTER and PETTIJOHN, 1963; KLEIN, 1967). In the field of uranium exploration and development, paleocurrent determinations have been useful guides in predicting the trend of relatively porous channels which localize uranium ore-bodies (REINECKE,

FIGURE 11

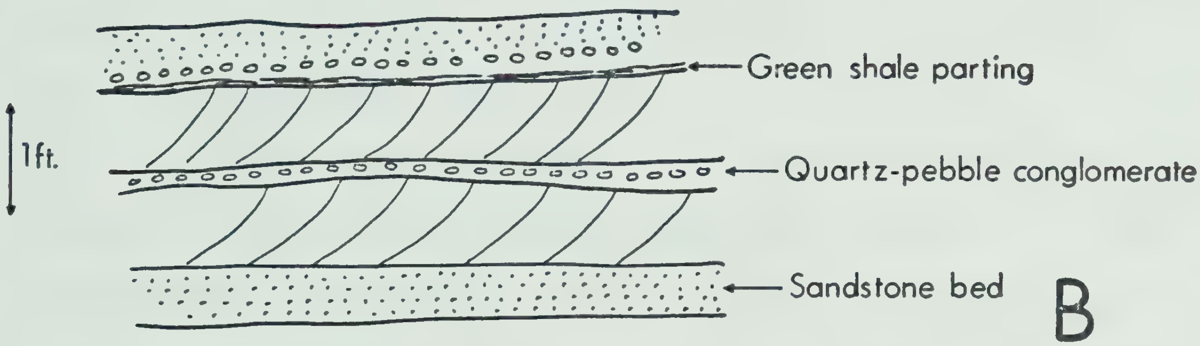
A: Deformed cross-bedding in the orthoquartzitic sandstone of the Middle Member, Kluziai Formation.

B: Cross-section of festoon cross-bedding in the Upper Member, associated with quartz-pebble lenses and shale partings.

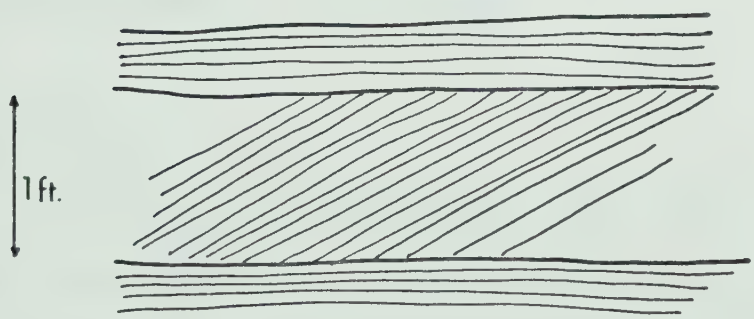
C and D: Simple cross-bedding in the parallel-sided, glauconitic siltstones of the Akaitcho River Formation.


1ft.

A


Green shale parting
1ft.
Quartz-pebble conglomerate
Sandstone bed

B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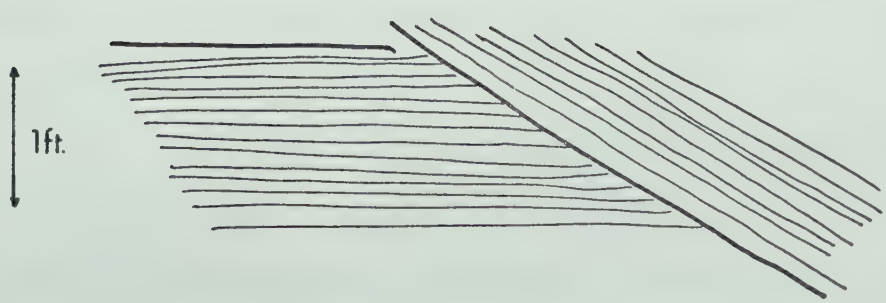
C


1ft.

D

1930; LOWELL, 1955; POOLE and WILLIAMS, 1956; PIENNAR, 1963).

Paleocurrent determination in the uraniferous Kluziai arenites was based primarily on cross-bedding orientations. More than 200 measurements of the orientation and dip of cross-bedding were made. Tectonic dip corrections were effected where necessary. The rose diagram (Fig. 12A) shows a unimodal paleocurrent direction from ENE to WSW. This result is in conformity with the general NE-SW regional paleoslope obtained by HOFFMAN (1969) for the Sosan Group (Fig. 12B).

The primary inclinations of cross-bedding in the Kluziai Formation is presented graphically in Figure 13. These inclinations range from 5° to 40°, with about 5% exceeding 33°, which is regarded as the angle of repose of sand in water. Soft-sediment deformation is most probably responsible for the few anomalous dips of cross-bedding.

Provenance

Paleocurrent evidence presented in Figure 12A suggests that the Kluziai Formation was derived from a source area that lay to the ENE, where presently exposed are Kenoran granites and metamorphics. The compositional and textural maturity of the Kluziai arenites may suggest that this source area was distant and probably of low relief.

The types of quartz occurring in sandstones have commonly been used to determine whether the source rocks are igneous, metamorphic or sedimentary. Due to the fine grain-size

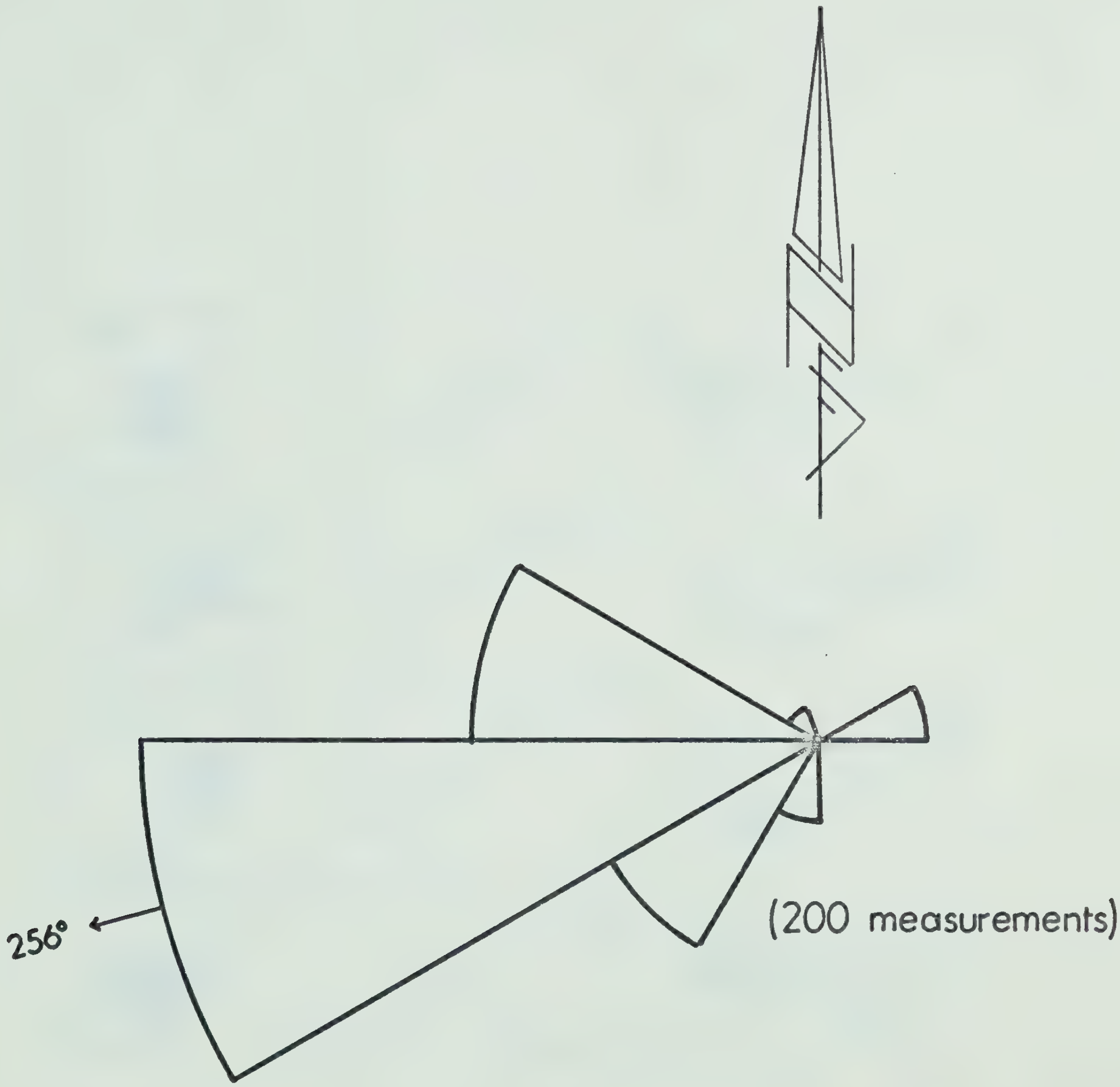


FIG.12A: Paleocurrent Rose Diagram of Crossbedding in Kluziai Formation, Toopon Lake Area, N.W.T.

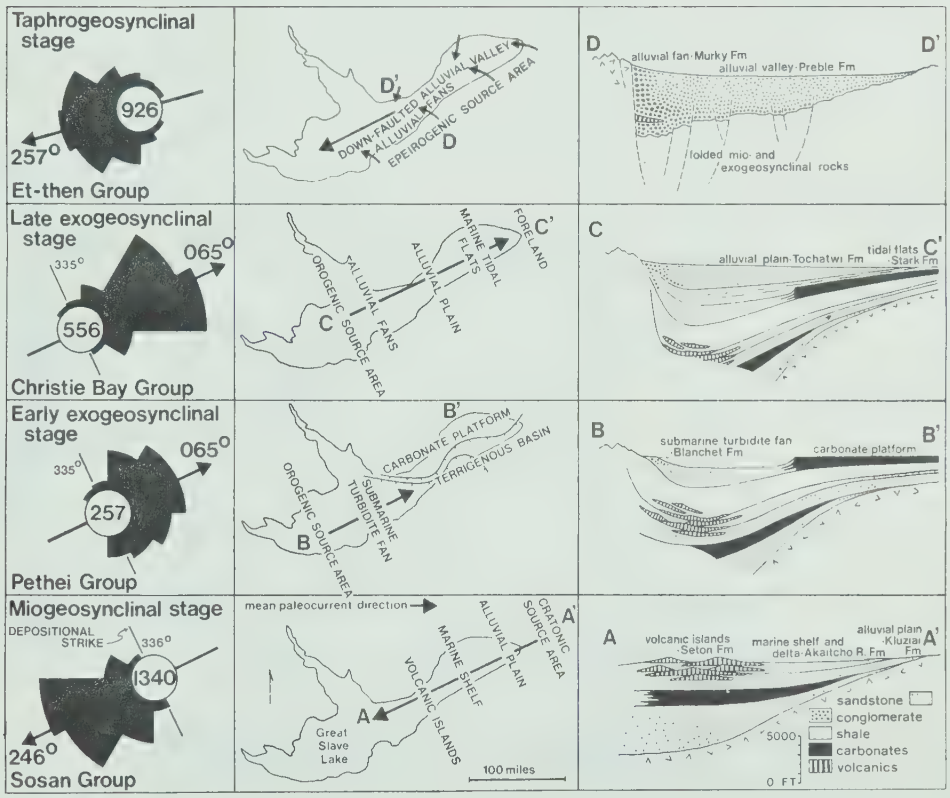


FIGURE 12B: Summary of the paleocurrents obtained by HOFFMAN (1969) for the rocks of the Great Slave Supergroup. (After HOFFMAN, 1969)

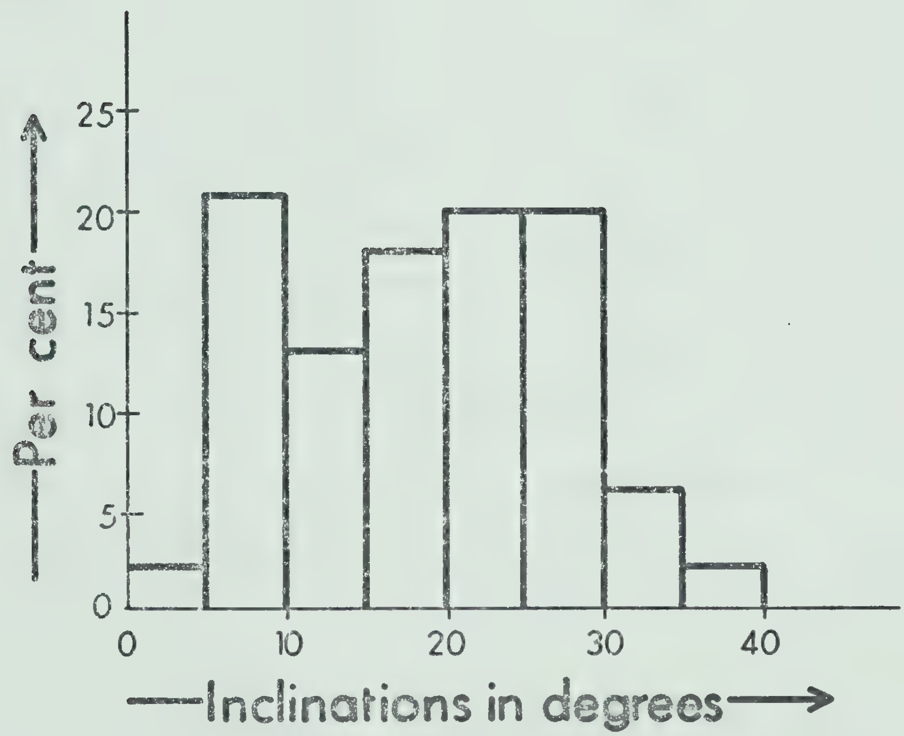


FIGURE 13: Primary inclinations of cross-bedding in the Kluziai sandstones.

of the Kluziai sandstones, it is difficult to speculate whether the quartz grains which are presently monocrystalline were initially polycrystalline or monocrystalline. However,the quartz-pebble conglomerate associated with these sandstones provides a rough clue. Most of these quartz pebbles are monocrystalline and exhibit straight to slightly undulose extinction (Plate 2-B). The few polycrystalline grains contain three to six composite grains that also show straight to slightly undulose extinction, with commonly sutured contacts. BLATT and CHRISTIE (1963), BLATT (1967) and FOLK (1968) note that these features are characteristic of plutonic quartz. The presence of minute mineral- and opaque- inclusions within the quartz grains further supports an igneous source for the sandstones of the Kluziai Formation.

The absence of abraded overgrowths on the quartz and feldspar grains rules out a sedimentary origin, although the high degree of textural maturity may be suggestive of recycling. However, FRAREY and ROSCOE (1970) note that the depositional environment rather than the provenance mainly determines the textural maturity of sandstones.

Towards the top of the Kluziai sequence, the content of muscovite increases. This probably reflects a substantial contribution of sedimentary material derived from muscovite-rich granites or less probably, from low-grade metamorphic rocks. Thus, it is concluded that the Kluziai Formation was derived mainly from Archean granitic rocks with probably minor contribution from low-grade metamorphics.

Environment of Deposition

The conditions under which the Kluziai Formation was deposited can be inferred from the lithologic nature, sedimentary textures and structures. The uniform lithology, substantial thickness, lateral extent, ubiquitous festoon cross-bedding, unimodal paleocurrent direction and the occurrence of mud cracks and shale-pebble conglomerates are suggestive of a non-marine and fluvial origin.

ALLEN (1965) presented models of alluvial deposition by braided, strongly meandering and low-sinuosity streams. Deposits of braided streams are often lenticular and consist of dominantly coarse material of bed load deposition. ALLEN (op. cit.) accounts for little or no fine-grained topstratum deposits being preserved because of the extensive 'combing' activity of anabranches. Deposits of low-sinuosity streams according to ALLEN are composed of tabular sheets of coarse-grained materials that extend through the width of the floodplain. In this environment, topstratum deposits are thin and laterally discontinuous. Floodplains of high-sinuosity streams have coarse sediments confined to narrow, linear bodies, while fine sediments deposited from suspension in floodbasins envelop and separate the meander belt sands laterally, and to a lesser extent vertically (ALLEN, 1965).

The sandstones of the Kluziai Formation in the study area, were deposited by braided streams. No fining-upward alluvial cycles characteristic of deposition by meandering streams

have been observed (ALLEN, 1964). The extensive lenticular bodies of festoon cross-bedded sandstones and quartz-pebble conglomerate represent bed load deposition in braided channels. Topstratum deposits which are quantitatively insignificant, comprise thin, mud-cracked,green, sericitic, shale partings and clay galls in the shale-pebble conglomerate. THOMPSON (1970), DOEGLAS (1962), and LATTMAN (1960), also observed that thin sequences of laterally and vertically restricted topstratum deposits are characteristic of riverplains of low-sinuosity and high— braiding streams.

The textural and compositional maturity of the Kluziai arenites is suggestive of deposition in loci of extensive sediment reworking. The unimodal paleocurrent direction is most characteristic of deposition by braided streams, in which variance of directional elements is usually small (ALLEN, 1965).

The intraformational boulder conglomerates that occur sporadically within this formation, most probably result from bed erosion or bank caving during anabranch wandering.

Thus, the Kluziai Formation was deposited by SW-flowing, braided streams with possible near-shore reworking at the base of the Formation. The fluvial environment which persisted throughout the deposition of the Kluziai Formation, gave way to the deltaic deposition of red, parallel-sided, micaceous, glauconitic siltstones of the Akaitcho River Formation.

Akaitcho River Formation

The Akaitcho River Formation is a vertically-graded sequence of red beds and orthoquartzite, which conformably overlies the Kluziai Formation. It outcrops extensively in the map-area and varies in thickness from about 30 ft. to 1000 ft. The Akaitcho River Formation is conformably overlain by the Seton Formation.

Wherever the Seton Formation is missing, the Akaitcho River Formation is hundreds of feet thick, and suceeded by the Gibralter Formation. On the other hand, the Akaitcho River Formation is tens of feet thick when the Seton Formation overlies it. This variation in thickness is probably due to stratigraphic equivalence between the Seton Formation and the upper part of the Akaitcho River Formation, as a result of spasmodic island volcanism interrupting sedimentation in a shallow marine environment.

The Akaitcho River Formation is subdivided into two Members: a White Orthoquartzite Member and a Glauconitic Siltstone Member.

White Orthoquartzite Member

This Member consists predominantly of uniformly- and medium-bedded, white orthoquartzite,which is light purple in a few exposures. The White Orthoquartzite Member outcrops north of Toopon Lake and is discontinuous or absent in a few local sections. It occurs most commonly in the lower part of the formation, although this stratigraphic position may shift upwards. The base of the

Member is characterized by the presence of about 20 cms. or more of red siltstone beds. This defines the contact between this Member and the sandstones of the underlying Kluziai Formation. The upper contact is gradational; within 20 to 30 cms the orthoquartzite passes into a purple sandstone and finally into red siltstone. The thickness of this Member varies from 30 to 50 ft.

In thin section, the orthoquartzite is fine-to medium-grained and well-sorted. The clastic grains are subrounded to rounded. Quartz constitutes about 92% of the rock. Fresh and partly sericitized orthoclase, microcline and plagioclase compose 7%, while muscovite, sericite and opaque iron-oxides form 1% of the rock.

Glauconitic Siltstone Member

The dominant rock type in this Member is a red, glauconitic micaceous siltstone. Other minor lithologic units are red, fine-grained sandstone and shale. The recessive Glauconitic Siltstone Member has a sharp lower contact which is due to lithologic and color contrast between the red siltstones and the underlying white sandstones. The upper contact is drawn at the base of the lowest bed of altered green spilitic tuff (Seton Formation) or thinly-laminated red and green shales (Gibralter Formation).

The red siltstone is thin-bedded and parallel-sided. This latter characteristic feature occurs throughout the sequence, with most beds possessing sharp bases. Thin beds and mottles of

green, sericitic siltstone interrupt the generally monotonous red-bed sequence. Sedimentary structures that occur in the siltstones include simple cross-bedding (Figs. 11C and 11D), ripple-marks, mud-cracks, flame structures and current lineations.

In thin section, this rock is a coarse-grained, equigranular, micaceous-glauconitic-quartz siltstone. Quartz occurs as subangular to subrounded grains which constitutes about 55-60% of the rock. The grain-size averages 0.06 mm. Feldspars, which are commonly altered, form 1-2%. Muscovite flakes with subparallel orientation make up 5-8% of the siltstone. Authigenic and euhedral glauconite (Plate 2-C), with an average grain-size of 0.2 mm forms 7 to 8% of the rock.

The matrix which is composed of opaque iron-oxides and sericite constitutes 25 to 30% of the mode.

Kahochella Group

The Kahochella Group consists of four Formations, (HOFFMAN, 1968) of which only the two lower Formations crop out in the Toopon Lake area (Table 3). The Seton Formation which is laterally equivalent to the Akaitcho River Formation in the map-area and throughout the southwest of the East Arm was not included in the Sosan Group by HOFFMAN (1968), but classified as the basal Formation of the Kahochella Group.

If HOFFMAN (op. cit.) followed strictly the recommendations of the Code of Stratigraphic Nomenclature (American Commission of Stratigraphic Nomenclature), the Seton Formation should

belong to the Sosan Group. Apart from being stratigraphically equivalent to the Akaitcho River and Kluziai Formations, the Seton Formation contains sandstones and siltstones that are strikingly similar to the two aforementioned Formations. Also, pyroclastic rocks occur within the basal Hornby Channel Formation of the Sosan Group (HOFFMAN, 1968; WALKER, 1971). All the aforementioned evidences suggest that the Seton Formation has more in common with the Sosan Group than the predominantly marine argillites of the Kahochella Group. It is therefore suggested that the Seton Formation be re-classified into the Sosan Group.

Seton Formation

In the Toopon Lake map-area, the Seton Formation conformably overlies and is in part laterally equivalent to the Akaitcho River Formation. The Seton Formation consists mainly of green basaltic tuff, maroon, quartz keratophyric tuff and volcanic sandstone, spilitic basalt flow, micaceous siltstone, agglomerate, tuff-breccia and tuffisite. A whole chapter (Chapter Six)in this thesis has been assigned to a detailed account of the petrology of the Seton Formation in the East Arm. The Toopon Lake section of the Formation will be described in that chapter.

Gibralter Formation

The Gibralter Formation crops out only along the south shore of McLean Bay (Fig. 8). It conformably overlies the

Seton Formation, but wherever the Seton Formation is missing, the Gibralter Formation overlies the Akaitcho River Formation. The top of the Gibralter Formation has been removed by erosion in the study area.

Lithogically, the Gibralter Formation consists of a monotonous sequence of finely-laminated, highly recessive, red and pale-green, calcareous shales. Calcareous concretions of various shapes occur abundantly within the Formation.

Intrusive Rocks

A N-S trending diabase dyke cuts the Gibralter Formation on the south shore of McLean Bay. This dyke also forms a prominent island within McLean Bay, and was erroneously mapped by STOCKWELL (1936) as extending as far south as the Murky Ridge. This dyke only extends for about 0.5 km from the McLean Bay shores.

Along the dyke's contact with the Gibralter Formation, contact metamorphism is evidenced by the 'baking' of the shales into a very dark-red color. Mineralogically, the diabase is composed of pyroxene, plagioclase feldspar, chlorite and iron oxides.

PLATE 2

PHOTOMICROGRAPHS OF THIN SECTIONS

A: Well-sorted, medium-grained orthoquartzitic sandstone of the Upper Member, Kluziai Formation. Crossed nicols. x 10.

B: Quartz-pebble conglomerate of the Upper Member of the Kluziai Formation. Most of the quartz pebbles are monocrystalline. Crossed nicols. x 5 (Toopon Ridge).

C: Authigenic glauconite in the micaceous, glauconitic siltstone of the Akaitcho River Formation. Plane polarized light. x 10 (Toopon Ridge).

D: Basaltic, lithic-vitric tuff, showing chloritized vitric shards, pumice, rock fragments and albite crystals in a basic vitroclastic matrix, Seton Island. Plane polarized light. x 5.

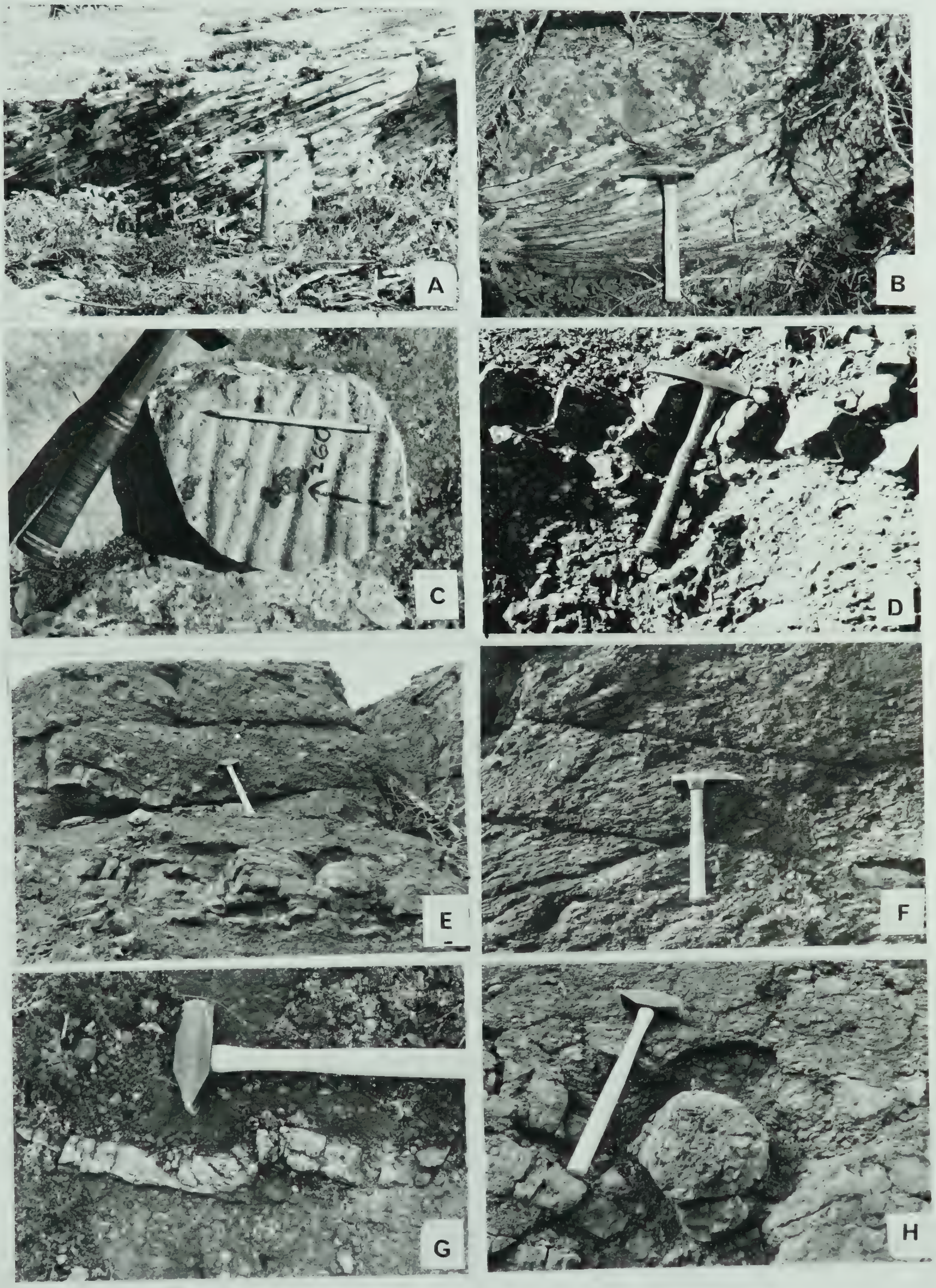
E: Quartz keratophyric tuff with tabular crystals of albite (An_{5-7}), quartz and volcanic fragments, set in a groundmass of devitrified glass and carbonate, Seton Island. Plane polarized light. x 5.

F: Fine-grained, trachytic, spilitic basalt. Plane polarized light. x 15 (Seton Island).

G: Porphyritic, spilitic basalt with plagioclase (An_{8-12}) phenocrysts. Plane polarized light. x 15 (Seton Island).

H: Amygdaloidal basalt with vescicles filled with albite, chlorite and quartz. Intersertal texture, with a groundmass of chlorite, iron-oxides and partly devitrified glass. Plane polarized light. x 15 (Seton Island).

PLATE 1



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C: Authigenic glauconite in the micaceous, glauconitic siltstone of the Akaitcho River Formation. Plane polarized light. x 10 (Toopon Ridge).

D: Basaltic, lithic-vitric tuff, showing chloritized vitric shards, pumice, rock fragments and albite crystals in a basic vitroclastic matrix, Seton Island. Plane polarized light. x 5.

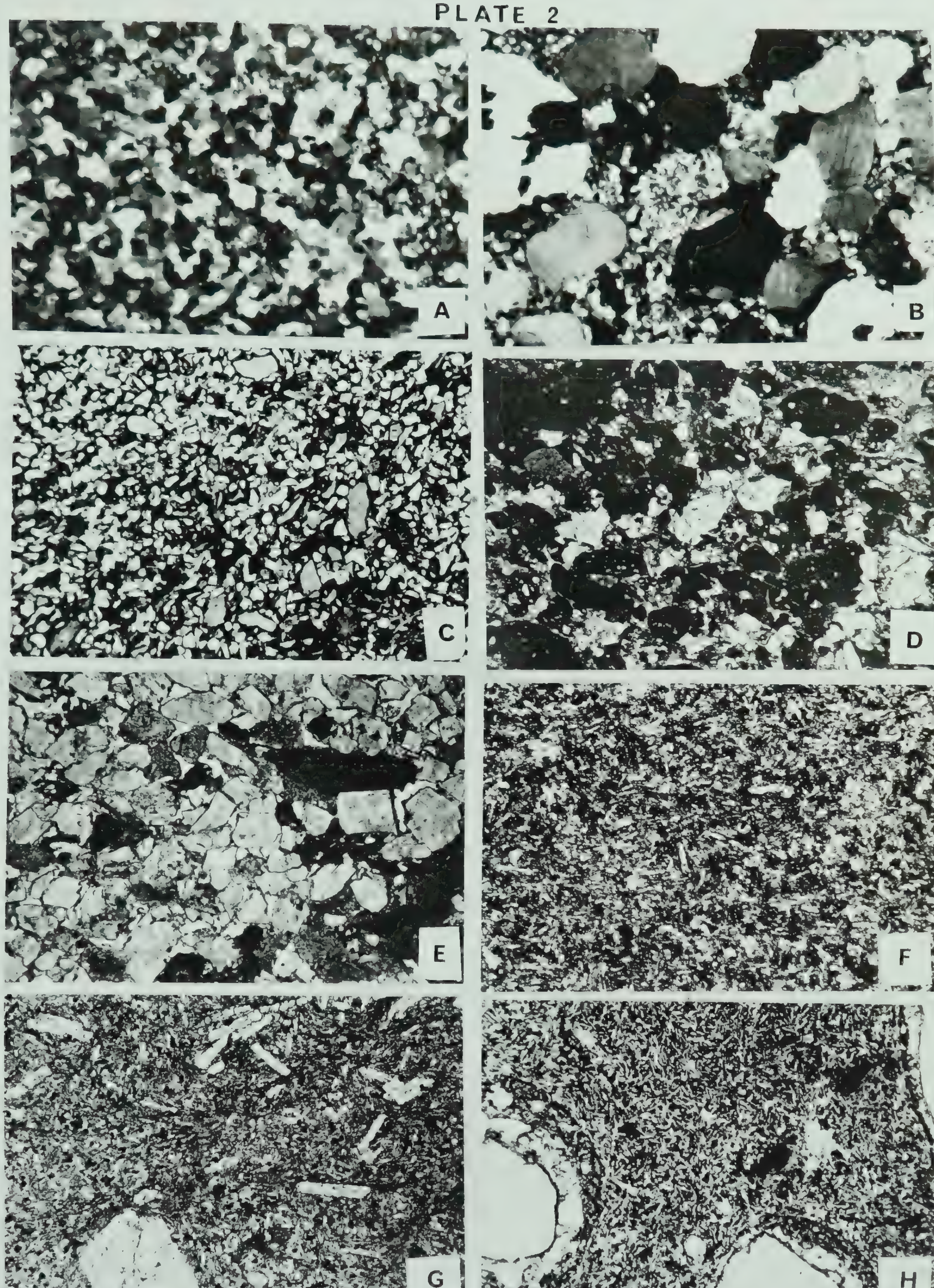
E: Quartz keratophyric tuff with tabular crystals of albite (An_{5-7}), quartz and volcanic fragments, set in a groundmass of devitrified glass and carbonate, Seton Island. Plane polarized light. x 5.

F: Fine-grained, trachytic, spilitic basalt. Plane polarized light. x 15 (Seton Island).

G: Porphyritic, spilitic basalt with plagioclase (An_{8-12}) phenocrysts. Plane polarized light. x 15 (Seton Island).

H: Amygdaloidal basalt with vescicles filled with albite, chlorite and quartz. Intersertal texture, with a groundmass of chlorite, iron-oxides and partly devitrified glass. Plane polarized light. x 15 (Seton Island).

PLATE 2



CHAPTER FOUR

STRUCTURE

Introduction

The structural geology of the Toopon Lake area is typical of the central and eastern parts of the East Arm, where most of the folds and faults trend northeast, paralleling the trend of the McDonald Fault system and the East Arm fold belt. The Aphebian rocks exposed within this region were probably deformed during the Hudsonian Orogeny (STOCKWELL *et al*. 1970).

The dominant structural feature in the map-area is the Toopon Lake anticline. Secondary folds and faults occur along the flanks of this major fold. The nature of deformation varies significantly, as a result of the association of different lithologic units, which exhibit varying degrees of structural competence.

The aim of this chapter is to describe the various structural features observed in the map-area, and to discuss the relationship between lithology and style of folding. Detailed mapping of the structurally-interesting areas was carried out on a scale of 1" = 500' (Figs. 14 and 15).

Folding

The Toopon Lake anticline is a NE-trending, asymmetric, major anticline, which plunges NE at an angle of 20° to

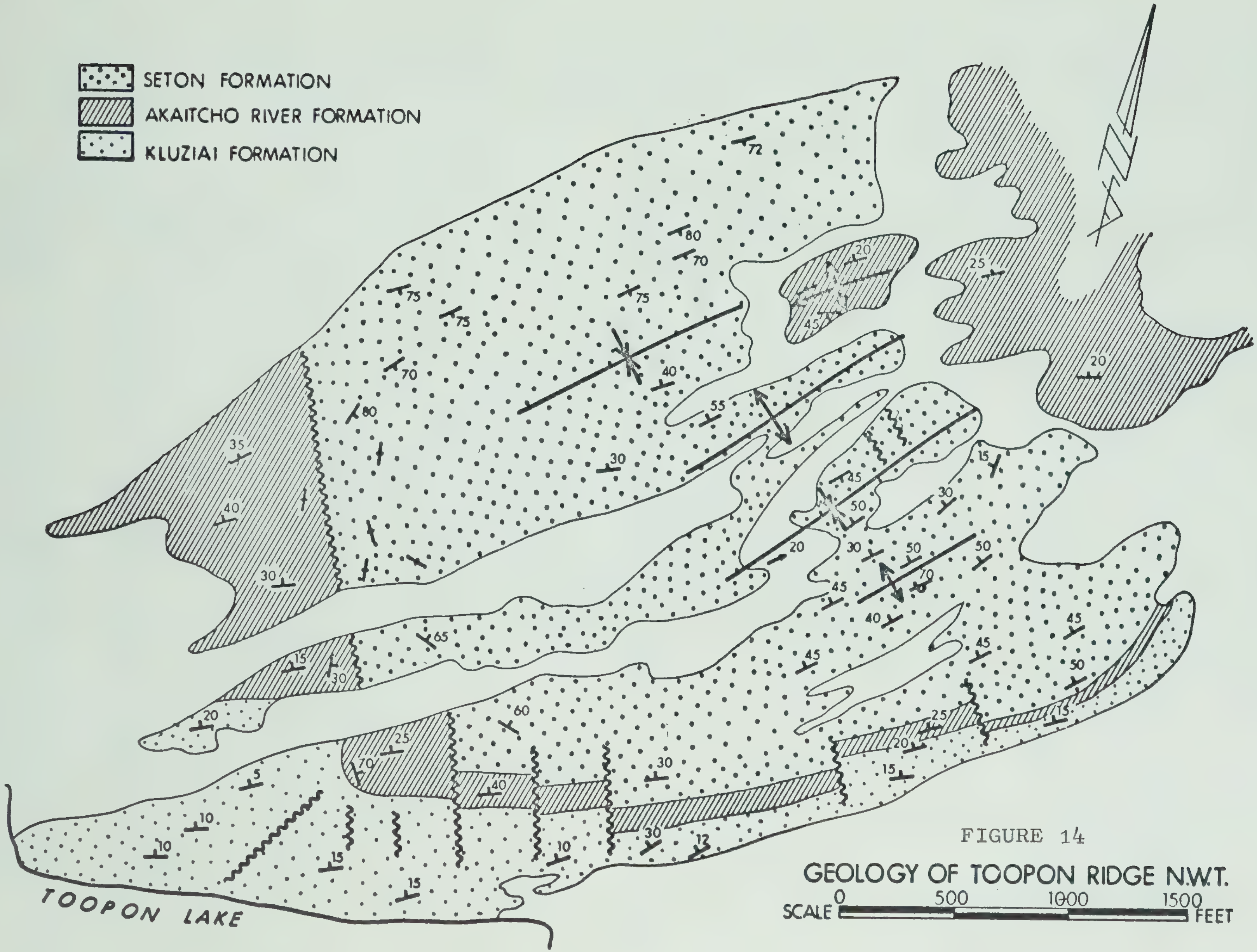


FIGURE 14

GEOLOGY OF TOOPON RIDGE N.W.T.

25° (Fig. 8). The anticline is about 1.5 km wide at the centre, and diverges southwestwards. It is conspicuously outlined by extensive outcrops of red,micaceous siltstones and sandstones of the Akaitcho River Formation. The SE limb of the anticline dips steeply (50°-75°) and is inverted in places. The NW limb is gently dipping except for few locally-developed, steep dips in incompetent beds.

Complex secondary folds characterize both limbs of the anticline. The most prominent of these secondary folds is an asymmetric syncline or structural basin which occurs on the NW limb (Fig. 14). This syncline is composed of two, small, elliptical basins and intervening domes, developed in the volcanic rocks of the Seton Formation. The western extremity or nose of the syncline is transected by a NNW-trending fault of moderate throw.

Folding on the Toopon Ridge (Fig. 14) is distinctly disharmonic. On the eastern extremity of the Ridge, a small elliptical basin in the Seton volcanics passes laterally into a small anticline, defined by outcrops of the underlying red siltstones of the Akaitcho River Formation. This structural discontinuity with depth is a product of varying structural competence and disharmonic folding. The amplitude of the folds developed in the incompetent siltstones and the more competent volcanics differ, resulting in an out-of-phase relationship in various areas.

Folding in the southeast limb of the anticline is

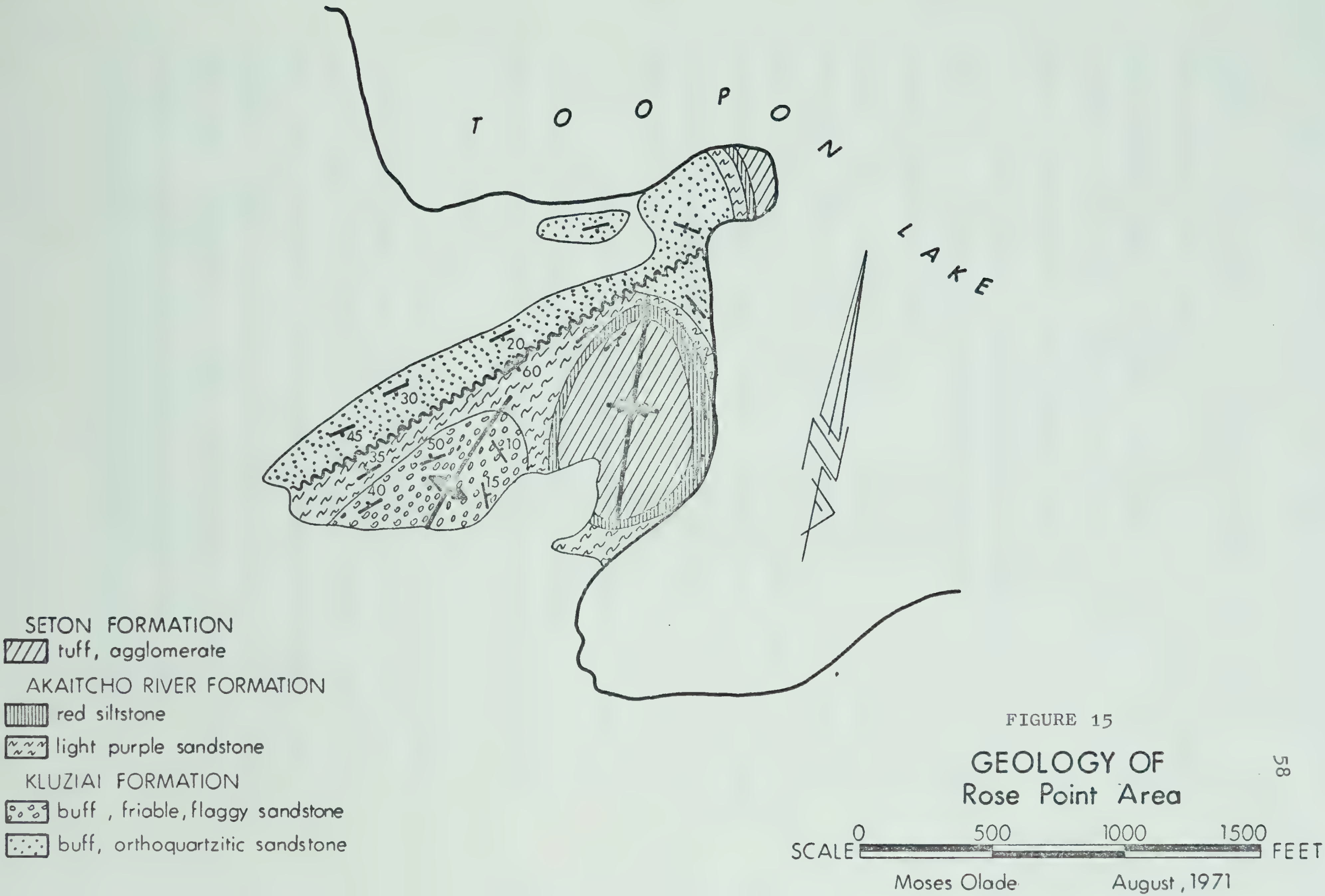


FIGURE 15

GEOLOGY OF
Rose Point Area

somewhat complex, due to the presence of many minor faults. In the Rose Point area, (Fig. 15) two small basins are separated by a NE-trending fault. Near the nose of the Toopon Lake anticline, deformation seems more penetrative and the rocks dip steeply and are overturned in certain areas (Fig. 8).

The nature of folding within the Toopon Lake area is determined by the varying structural competence of the deformed lithostratigraphic units.

The competent sandstones of the Kluziai Formation are apparently little affected by the deformation, except near the nose of the fold on the SE limb, where the sandstones are faulted and exhibit steeper dips. Broad flexures which can be discerned by detailed mapping on a large scale, characterize the sandstones throughout the area.

The incompetent, thin-bedded, crumbly siltstones of the Akaitcho River Formation folded concentrically and were deformed by thinning on the flanks and thickening at the hinge of the anticline.

The volcanic rocks of the Seton Formation are preserved in structural depressions, and seem to have behaved more competently than the underlying siltstones. SPENCER (1969) notes that when a competent unit which has tended to maintain some element of coherence during deformation is underlain by incompetent beds, complicated folding usually arises. The volcanic rocks in the map-area are complexly deformed and commonly characterized by a basin and dome geometry (Figs. 14 and 15).

Faulting

The faults exposed in the Toopon Lake area exhibit two major trends; NE and NNW.

The most prominent of the NE-trending faults is the Murky Ridge Fault (Fig. 8) which REINHARDT (1969) considered as a direct splay from the McDonald Fault. Other faults exposed within the southern part of the map-area are probably related to the NE-trending McDonald Fault system. In the area south of Toopon Lake, the only exposure of the Duhamel Formation occurs as a result of uplift on the footwall side of a fault plane. The confused bedding orientations in the incompetent calcareous shales of this Formation may be attributed to the somewhat complex faulting in the area.

Minor faults exhibiting the NE trend occur near the crest of the Toopon Lake anticline. These faults which may not be related to the McDonald Fault system were probably associated with the tension that developed near the nose of the fold.

Vertical displacements on the NE-trending faults vary from a few feet to hundreds of feet. A prominent scarp accompanies the Murky Ridge Fault; here, the friable conglomerates are highly silicified. It is significant to note that apart from mylonitization and silicification, no major quartz-veining accompanied the faulting, as observed in other parts of the East Arm.

Northnorthwest trending faults occur on the flanks of the Toopon Lake anticline. These faults are mainly normal

faults with displacements varying from a few feet to tens of feet. On the Toopon Ridge (Fig. 14), many faults of this class were mapped. The distinct Kluziai-Akaitcho contact forms an excellent 'marker' feature, to trace and delineate the offsets. In this locality, the red siltstones of the Akaitcho River Formation are repeatedly displaced against the sandstones of the Kluziai Formation. Slickensides were commonly observed on the fault planes.

The exact age relationship between the NE- and NNW-trending faults is not evident in the Toopon Lake map-area. REINHARDT (1969) noted that movements on the Mc Donald Fault system started prior to the deposition of the Great Slave Supergroup and continued until Helikian times. Thus, the NE-trending faults related to the McDonald system are probably older or penecontemporaneous with the tensional, NNW-trending faults. This supposition is in conformity with the observations of WALKER (1971) and REINHARDT (1969b) in the Simpson Islands area.

Jointing and Fracturing

Joints and fractures are very common in the sandstones of the Kluziai Formation. The thin-bedded siltstones of the Akaitcho River Formation possess a crumbly or recessive nature, and this has made a quantitative study of the joints difficult. One hundred and five measurements of attitudes of joints and fractures in the Kluziai sandstones were carried out during field-mapping. Figure 16 presents the contoured equal-area projection and contours of the poles to the joints and fractures. Three major joint-sets are

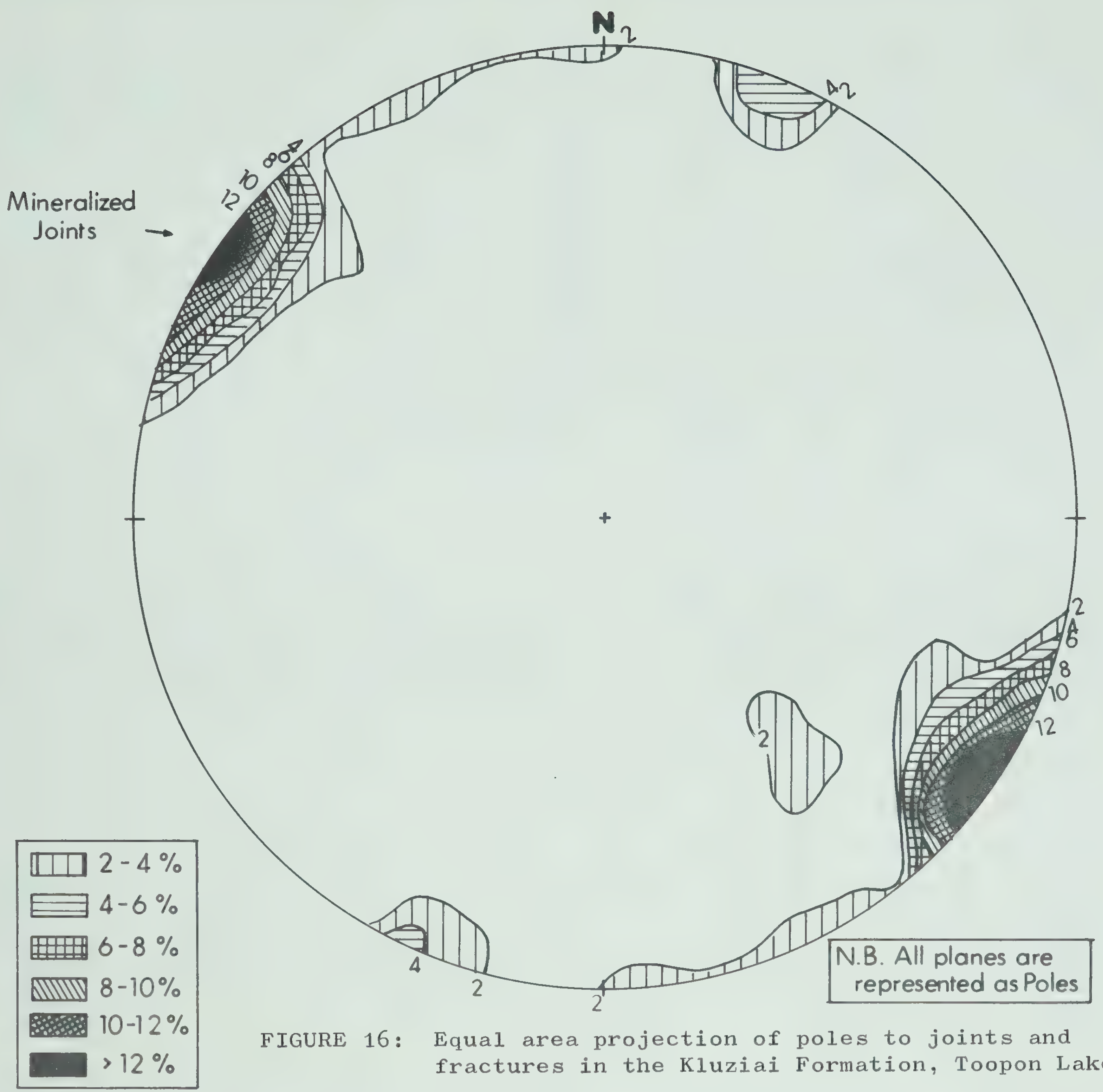


FIGURE 16: Equal area projection of poles to joints and fractures in the Kluziai Formation, Toopon Lake area.

discernible in the diagram. The major set occurs along a plane which strikes approximately NE and is slightly inclined to the structural trend of the area. Slickensides are common on the joint surfaces of this set. The second joint-set trends NNW while the third set, although of low point concentration, trends NNE.

Secondary uranium mineralization commonly occurs on the ENE- and NNE- trending joints while the other joint set is rarely mineralized.

Features observed on fracture or joint surfaces include stylolites and slickensides. Quartz veining is not associated with any of the joint sets.

Discussion and Conclusions

The most striking aspect of local tectonic features in the Toopon Lake area is the acute disparity between structures in the different Formations. The nature of structural deformation was apparently affected by the varying competence of the folded units. Folds in the Seton volcanics often have no counterpart in the underlying Akaitcho River Formation, and structural discontinuity is apparent at depth. The competent Kluziai arenites seem unaffected by the deformation while the Akaitcho River Formation has behaved incompetently, folded concentrically and is bounded on both lower and upper surfaces by planes of *décollement*. As a result, the overlying, more competent volcanics deformed complexly. Also, the orientation of principal stress directions was such that basin and dome structures formed within the

volcanics.

A minor discordance in axial trends exists between the major anticline and few of the secondary folds (Fig. 8). This discordance is explicable by, either disharmonic folding during a single deformational episode, or bi-episodal deformation.

The lateral offsets of bedding associated with the NNW-trending faults are, most probably, features of dilation associated with folding.

The attitudes of joints and fractures may be related to the structural trend and folding in the area. Based on the assumption that the direction of maximum principal stress in the area was normal to the fold axis, the steeply-dipping, NE-trending joints probably represent shear joints as evidenced by the common occurrence of slickensided joint surfaces. The NNW-trending joints which are normal to the fold axis and do not have slickensided surfaces or show offsets are possibly of tensional origin and may be related to the NNW-trending tensional faults. The gently- to steeply-dipping joints exhibiting the NNE trend and occurring along the crest of the fold are probably related to the tension which developed along the hinge of the fold during deformation.

CHAPTER FIVE

URANIUM MINERALIZATION

Introduction

Radioactive occurrences were first discovered within the Toopon Lake area in 1970, during a reconnaissance scintillometer survey conducted by Vestor Explorations Ltd. Uranium mineralization is localized within sandstones of the Kluziai Formation. The mineralization is epigenetic, peneconcordant and characterized by a mineral association of pitchblende-graphite-pyrite-chalcopyrite, which is interstitial between the quartz grains. These radioactive occurrences are of academic interest because they occur in Precambrian sandstones and also contain possible evidence of hydrocarbons or organic activity.

In the following discussion of radioactivity, all radiation levels, given in counts per second (c.p.s.), refer to total count radiation as measured with a SRAT SPP-2-NF scintillometer, utilizing a Thallium-doped NaI scintillator, 1.5 inches in diameter and 1 inch thick.

The purpose of this chapter is to describe the nature, controls and origin of uranium mineralization in the area, based upon field and laboratory studies.

History of Uranium Exploration

In 1969 Vestor Explorations Ltd. purchased a group of claims located on North Simpson Island in the SW of the East Arm, after the presence of radioactive showings were noted by Mr. E. Jones who initially staked the area for minor gold and chalcopyrite in a quartz vein. Further scintillometer survey by Vestor Explorations Ltd. revealed the presence of several radioactive occurrences within the sandstones and conglomerate of the basal Hornby Channel Formation.

The initial success of the survey on Simpson Islands and the apparently stratiform nature of the occurrences prompted further staking of claims covering other sandstone outcrops in various areas within the East Arm, including the Toopon Lake area.

In the summer of 1970, a reconnaissance scintillation survey was conducted on all sandstones of the Sosan Group cropping out in the Toopon Lake area. Several radioactive occurrences that are often continuous for tens or hundreds of feet and accompanied in places by gummite or hematite staining were discovered within the Kluziai Formation of the upper Sosan Group.

During the 1971 summer field-season, detailed radiometric prospecting was carried out, using a SRAT-Model SPP-2 scintillometer. Several new radioactive 'showings' were detected and three zones of appreciable extent and characterized by continuous radioactivity were delineated. Ground control was established by setting up base and picket lines. Grid-controlled, detailed geologic mapping and radiometric surveys preceeded trenching in

mineralized areas. Trenching revealed that surface radioactivity continued at depth, although it was spurious in few areas. Fresh blasted samples assayed 0.05 to 0.56% U_3O_8. Further drilling, which will determine the extent of mineralization at greater depth, is planned for the near future.

Nature and Types of Mineralization

Radioactive occurrences in the Toopon Lake area are predominantly localized within the well-sorted, orthoquartzitic sandstone of the Middle Member of Kluziai Formation. Spurious radioactivity has also been observed within the clay-gall conglomerates, and the calcareous sandstone of the Lower Member. Moderate hematite staining, and in rare cases gummite staining accompany the mineralization on the surface. The uranium mineralization which is disseminated, commonly occurs in zoned patches of black or dark-grey sandstone. The cores of these zoned bodies (Fig. 17) contain dark grey uraniferous sandstone which is enveloped by a limonite-stained rim and outwardly fringed by red hematite staining.

Uranium mineralization in the Toopon Lake area is obviously epigenetic, but lacks any evidence of accompanying hydrothermal alteration. Two types of mineralization have been recognized.

The first type of mineralization is termed the 'primary' or 'reduced' type. This type of mineralization has only been seen as a result of blasting or trenching in areas of anomalous radio-

FIGURE 17

A and B: Sketch maps showing the distribution of mineralization within blasted trenches. (Contour lines in counts per second join area of equal radioactivity)

C: Diagrammatic representation of mineral zonation within uraniferous sandstone patches. (Hem. St - Hematite staining; Lim. St. - Limonite staining)

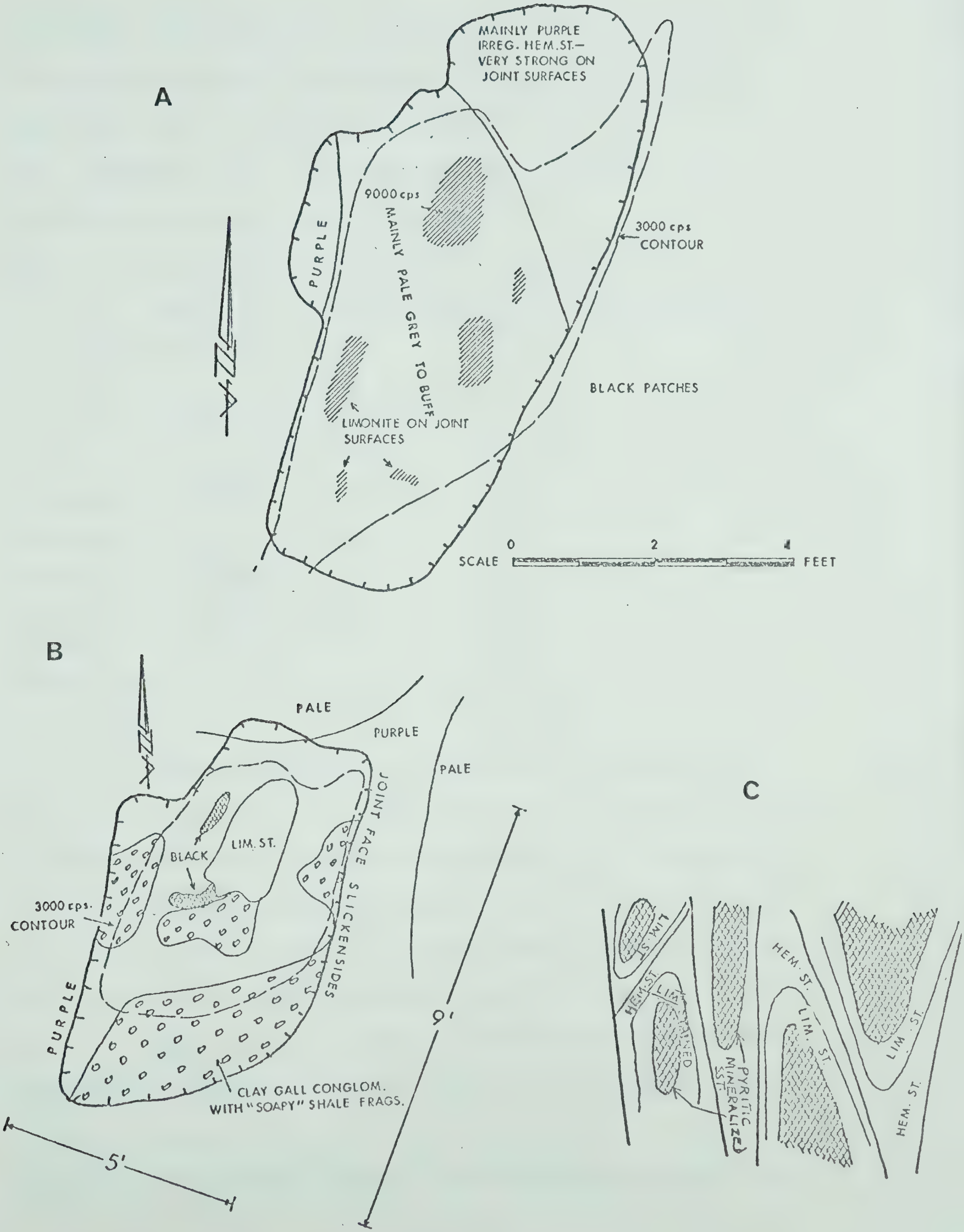

A
MAINLY PURPLE IRREG. HEM. ST.— VERY STRONG ON JOINT SURFACES
PURPLE
9000 cps
MAINLY PALE GREY TO BUFF
3000 cps CONTOUR
BLACK PATCHES
LIMONITE ON JOINT SURFACES
SCALE
0
2
4
FEET
B
PALE
PURPLE
PALE
BLACK
LIM. ST.
JOINT FACE SLICKENSIDES
3000 cps. CONTOUR
PURPLE
CLAY GALL CONGLOM. WITH "SOAPY" SHALE FRAGS.
5'
9'
C
LIM. ST.
HEM. ST.
LIM.
PYRITIC MINERALIZED SST.
HEM. ST.
LIM. ST.
LIM. ST.
HEM. ST.

FIGURE 17

activity. The mineralized sandstone is dark grey to black and contains disseminated pitchblende, pyrite and chalcopyrite. Commonly, 2 mm-wide veinlets of radioactive material follow very thin fractures within the sandstone. Thin section studies of the mineralized sandstone reveal that the ore minerals occupy intergrain interstices within the host rock (Plate 3-D).

Grab assays from this type of mineralization show the following results:[1]

	Wt.% U_3O_8 (Chem.)	Wt.% Cu	Wt.% Co	Ag oz/ton	Au oz/ton
Sample 1	0.17	0.15	0.02	Tr	Tr
Sample 2	0.51	0.05	n/d	0.24	Tr
Sample 3	0.053	n/a	n/a	n/a	n/a
Sample 4	0.56	0.20	n/d	n/d	Tr
Sample 5	0.41	0.15	0.02	n/d	Tr

The second type of mineralization is termed the 'secondary' or 'oxidized' type. It is characterized by secondary uranium minerals and secondary ferric-oxides and -hydroxides. This type of mineralization is commonly observed at the surface, whilst in blasted trenches it occurs along fractures or interstitially within those sandstones adjacent to the fractures.

The 'oxidized' type of mineralization was probably produced by supergene leaching of the primary minerals and sub-

1 Values from private company file (Vestor Explorations Ltd.).

sequent concentration in fractures. This type of mineralization itself is not of economic value, but may indicate proximity to the more economically significant 'primary' type of mineralization.

Mineralogy

The identification of ore- and associated- minerals was based upon combined mineralographic, X-ray and petrographic methods.

Pitchblende is the only primary uranium mineral in the Toopon Lake mineralization. It occurs disseminated within the sandstone interstices and less frequently as tiny veinlets. In autoradiographed, polished sections, the pitchblende is seen to be very fine-grained, euhedral or anhedral. It is grey, non-bireflectant, isotropic, and exhibits low reflectance (10-15%). Approximate grain size ranges from 0.01 to 0.02 mm. The pitchblende commonly forms a complex intergrowth with graphite, as shown on Plates 3-A to 3-C. This graphite is somewhat fibrous, whitish-yellow (in oil), strongly bireflectant, strongly anisotropic (yellowish-green-grey) and exhibits parallel extinction. The mineral shows a good cleavage and its reflectance is about 20-25%.

Pyrite and chalcopyrite ubiquitously accompany the uranium mineralization. The sulfides are coarser than the pitchblende-pyrite intergrowth and can often be identified megascopically. Their average grain size is about 0.07 mm and they are variably shaped and show no evidence of abrasion. Commonly, the

pyrite shows a red internal reflectance at its rims, which indicates its incipient alteration to hematite.

'Gummite' was the name applied to a fine-grained mixture of various secondary uranium minerals encountered at surface. A few of these minerals have been identified by X-ray diffraction techniques. Green cuprosklodowskite, ($CuO.2UO_3.2SiO_2.6H_2O$) occurs along fractures in the mineralized rocks, and is obviously a product of supergene leaching of the pitchblende and the associated copper sulfides. Other secondary uranium minerals identified were: liebigite ($Ca_2(UO_2)(CO_3)_3.10H_2O$) and soddyite ($5UO_3.2SiO_2.6H_2O$).

Hematite and less commonly goethite are sometimes associated with the uranium mineralization. Often exposed at the surface, the hematite staining can in some cases be used as a guide to ore. In the trenches, zones of goethite and hematite often rim the grey uraniferous sandstone.

Barite was observed as 3-5 mm long, tabular crystals occurring within the mineralized sandstone. A greyish-green variety of chlorite, identified by X-ray technique, is rarely associated with the mineralization.

Relationship of Mineralization to Stratigraphy and Structure

The distribution of radioactive occurrences within the Toopon Lake area suggests a distinct element of stratigraphic control. Most of the occurrences (Fig. 8) are confined to the Middle Member of the Kluziai Formation. Also, uranium mineral-

ization occurs only within the well-sorted orthoquartzitic sandstone of the Middle Member. This is probably due to the higher permeability of the well-sorted sandstone. The unmineralized Upper and Lower Members are, in comparison, poorly to moderately sorted, and have calcareous cement. GRIFFITHS et al. (1954) report that in the Salt Wash (Colorado) uranium deposits, silica cement appears to be associated with ore, whereas carbonate cement is associated with barren sandstone. Conversely, DODD (1956) has reported the localization of uranium deposits within carbonate-impregnated sandstone. Further development of the Toopon Lake radioactive zones will hopefully reveal any other influence of stratigraphy or lithofacies on ore localization.

Structural control of the 'secondary' or 'oxidized' type of mineralization is apparent at the surface and in the trenches. The secondary uranium minerals always occupy fractures and joints within the sandstone. The fact that the 'secondary' type of mineralization is the most apparent at the surface and in radiometric anomalies may sometimes lead to the misconstrued conclusion that all of the Toopon Lake mineralization is fracture-controlled. It is quite evident however, that the structural control is post-ore, and that the stratigraphic-lithological control is the dominant factor.

Genesis of Uranium Mineralization

In discussing the origin of the Toopon Lake mineralization, many of the suggestions remain purely speculative, and

final conclusions will have to await further information on the nature of the mineralization at depth. This information will be available as soon as exploratory drilling is carried out.

Uranium mineralization in the Toopon Lake area is interstitial within the fluvial sandstone of the Kluziai Formation. The ore minerals are not detrital and no structural control of the primary uranium mineralization is apparent. Therefore, the radioactive occurrences may be regarded as peneconcordant (FINCH, 1959) and grouped into the class of epigenetic 'sandstone-type' uranium mineralization.

The lack of alteration in those rocks adjacent to the radioactive occurrences suggests deposition by low temperature solutions of near neutral pH, the range within which uranyl di-carbonate and tricarbonate complexes are stable (HOSTELIER and GARRELS, 1962). The generally low content or absence of thorium in the radioactive occurrences may further attest to the fact that uranium was transported as a hexavalent complex (NASH, 1968).

The factors effecting precipitation of the ore minerals are also subject to speculation. Precipitation could have been the result of a decrease in pressure, changes in pH and/or Eh of the ore solutions, or to changes in porosity within the braided-channel deposits. The association of graphite with the pitch-blende is however suggestive of an Eh control by hydrocarbons or other organic materials.

The source of the uranium and other associated metals (Cu, Co, Ag) might be one of the following possibilities: (1) mag-

matic hydrothermal solutions, or (2) leaching of overlying volcanic debris.

Magmatic hydrothermal solutions seem to be the less likely source of the elements in the Toopon Lake mineralization. There is no evidence of hydrothermal activity near the uranium occurrences, and no known igneous intrusion is seen to occur in the vicinity of the uraniferous sandstones.

The more plausible source of the U and Cu is the devitrified volcanics of the Seton Formation, which almost directly overlie the radioactive occurrences. Pyroclastic and volcanic rocks have commonly been suggested as sources of uranium in many 'sandstone-type' deposits in Colorado and Wyoming (KOEBERLIN, 1938; LOVE, 1952; LOVE, 1953; VINE, 1956; HARSHMAN, 1970). DENSON and GILL (1956) amply demonstrated that the uraniferous lignite deposits of South Dakota derived their uranium from the leaching of overlying pyroclastic rocks. The Seton volcanics which will be described in detail in the next chapter (Chapter Six), comprise a spilite-keratophyre suite, commonly containing disseminated sulfides. The 'spilitization' process, which in the Seton volcanics is partly a syn- or post-consolidation autometasomatism, is commonly associated with metallic mineralization - for example, Cu, Mn (AMSTUTZ, 1958). In this context, it is pertinent to note that JURAIN and RENARD (1970) suggested that chloritization of micas tends to liberate uranium from the mineral structure. A similar process might therefore be evoked for the release of uranium from volcanic glass by the chloritization which accompan-

ied spilitization in the Seton volcanics.

Thus, in the spilitized volcanic and pyroclastic rocks of the Seton Formation,geochemical enrichment of uranium may have been effected in two ways: (1) chloritization and devitrification of the volcanic glass, and (2) alkali metasomatism associated with the spilitization. SØRENSEN (1970) reported the association of uranium mineralization with bostonite (albitite) in Colorado. It may also be significant to note that in the Simpson Islands' uranium occurrences, bostonite fragments or breccia encountered in drill cores are sometimes slightly radioactive (J. GREIG, personal communication). It has been suggested that the Simpson Islands' bostonite probably represents a subvolcanic phase associated with the Seton volcanism (MORTON, 1970). SØRENSEN (1970) also noted that alkali basalts are apparently richer in uranium than tholeiitic basalts. Therefore, the spilitized Seton volcanis might well be postulated as a source of uranium for the Toopon Lake occurrences.

A genetic model which best explains most of the features characteristic of the Toopon Lake mineralization is as follows: Uranium and other associated metals already enriched in the volcanics were, during spilitization and diagenesis leached by connate waters in the form of $\left[UO_2(CO_3)_2\right]^{2-}$ or $\left[UO_2(CO_3)_3\right]^{4-}$ ions and Cu-Co salts. These ions and salts were subsequently transported in downward- or laterally-migrating, alkaline, carbonate-rich solutions. The ore minerals were finally precipitated in porous braided-channel deposits within the partly-consolidated

well-sorted sandstone as a result of changes in pH and/or Eh of the solutions, effected in part by the action of organic matter.

The 'secondary' mineralization now observed at the surface, was then subsequently produced by supergene leaching into post-ore joints associated with the folding.

PLATE 3

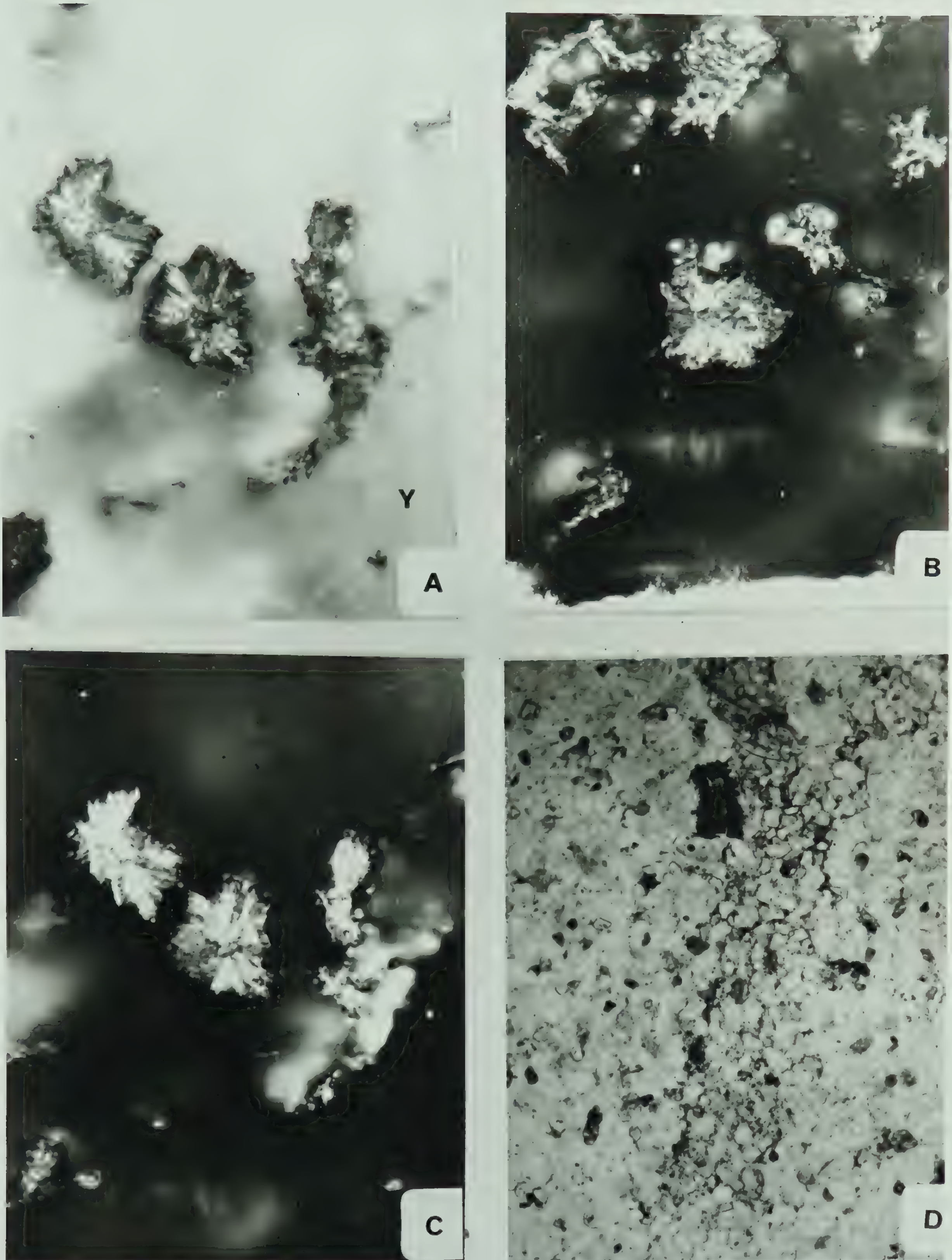
PHOTOMICROGRAPHS OF POLISHED AND THIN SECTIONS

A: Intergrowths of pitchblende (dark) and graphite (white) under plane polarized light. x 700 (Toopon Lake).

B and C: Pitchblende-graphite intergrowths under crossed nicols. x 700 (Toopon Lake).

D: Veinlet of radioactive material occupying interstices within orthoquartzitic sandstone. Plane polarized light. x 15 (Toopon Lake).

PLATE 3



CHAPTER SIX

PETROLOGY OF THE SETON VOLCANICS

Introduction

Within the East Arm of Great Slave Lake, Northwest Territories, a 1300 m thick sequence of volcanics, iron formation, volcanic sandstones and interbedded jasper and marine sediments, constitute part of the Proterozoic succession. The volcanogenic rocks are exposed throughout the sedimentary basin, extending from Blanchet Island in the SW to the Fort Reliance area in the NE, and comprise the principal phase of Proterozoic volcanism in the East Arm Subprovince. Associated hypabyssal alkaline intrusions represent subvolcanic phases. HOFFMAN (1968) named these rocks the Seton Formation, after the type section occurring on Seton Island.

The volcanic rocks of the Seton Formation were earlier described as 'greenstones' by LAUSEN (1929). STOCKWELL (1932, 1936) mapped and briefly described these rocks as 'amygdaloidal and pillow andesite', but did not provide any petrographic descriptions. BARNES (1951, 1952) mapped and described the same rocks as "basaltic flows". Finally, HOFFMAN (1968, 1969), after his regional stratigraphic study of the East Arm, regarded the Seton Formation as a stratigraphically complex assemblage of andesite and minor rhyolites, with intercalated basic- and acid-volcaniclastics, that required a more detailed study.

Despite their frequent mention in previous publications, the Seton volcanic rocks have never been extensively studied, and their exact nature and petrological characteristics remain undefined.

The purpose of this chapter is to present the results of geologic mapping, petrographic and bulk petrochemical studies of the Seton volcanics from Seton Island (type section), the Toopon Lake section and the Fort Reliance area of the East Arm. An attempt has been made to correlate the Formation between these areas.

Description of the Seton Formation

General

The rocks of the Seton Formation named after the type locality of Seton Island by HOFFMAN (1968) were formerly classified as belonging to the Kahochella Formation by STOCKWELL (1936). The Formation varies in thickness; from approximately 40 m thick in the NE to 1300 m thick in the SW of the East Arm. HOFFMAN (1968, 1969) observed that the Seton Formation was encountered only within the southwestern half of the East Arm fold belt, and interpreted this as due to a transition from stable-shelf sedimentation in the NE to sedimentation of a more eugeosynclinal character in the SW. However, the present study has clearly revealed that the Seton Formation is exposed throughout the East Arm and consequently, any tectonic significance previously attributed to the distribution of exposures may not be relevant.

The Seton Formation contains basaltic flows, trachyte, quartz-keratophyric and basaltic tuffs, diatreme breccias, volcanic sandstones, jasper beds, iron formation and interbedded, marine epiclastic rocks. The Formation lies conformably upon the Akaitcho River Formation in the NE, but towards the SW of the East Arm, it becomes laterally equivalent to the marine, Akaitcho River and upper Kluziai Formations.

The Seton volcanism was apparently mainly subaerial, although the occasional occurrence of pillow structures has been reported by STOCKWELL (1936) and N. BADHAM (1971, personal communication). Penecontemporaneous facies variations associated with island volcano environments (HUGHES and BRÜCKNER, 1971) were observed on Seton Island and suggest that a volcanic island complex existed, which was commonly submerged on its flanks by shallow marine waters, as evidenced by the occurrence of ripple marks, gypsum casts and cross-stratification in the volcaniclastic rocks.

A petrographic and stratigraphic description of the Seton Formation from Seton Island, Toopon Lake and the Fort Reliance area follows. The nomenclature employed is generally that of WILLIAMS et al.(1954). For the volcaniclastic rocks, FISHER's (1961) classification has been utilized.

Seton Island

On Seton Island (Fig. 18), the Seton Formation is some 1300 m thick and conformably overlies the lower part of the

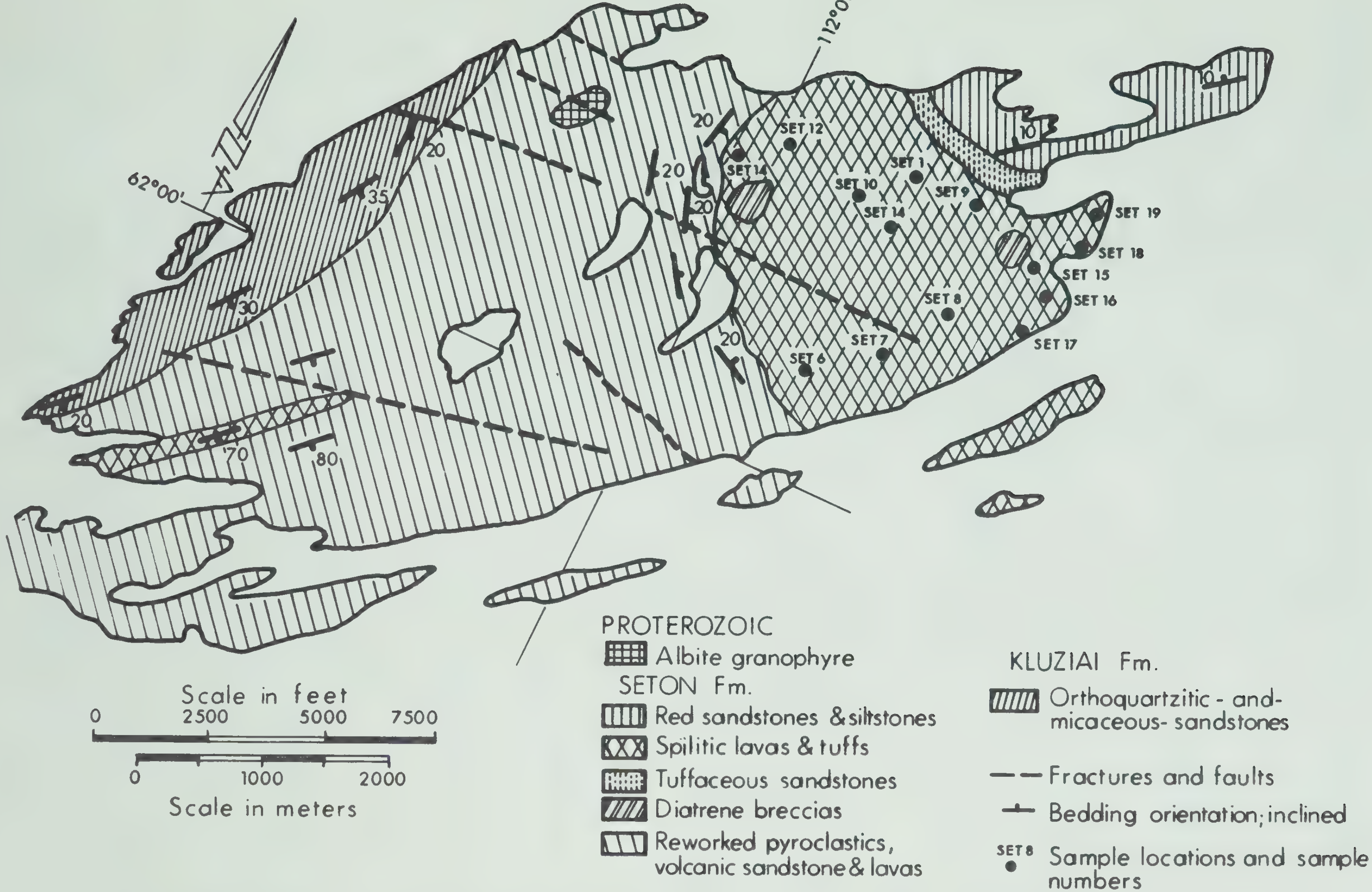


FIGURE 18: Geologic Sketch Map of Seton Island
East Arm of Great Slave Lake, N.W.T.

Kluziai Formation. Sandstone and siltstone beds remarkably similar in appearance to those occurring in the Akaitcho River and Kluziai Formations are also found in the Seton Formation. The Akaitcho River Formation is totally missing from the Seton Island section (Fig. 19).

The lithologic units characterizing the Seton Formation on Seton Island are; spilitic basalt, spilitic- and quartz keratophyric- tuffs, vent breccias, agglomerate, volcanic sandstones and clastic sediments.

The volcanic activity was apparently cyclical as shown in Figure 19; each volcanic episode usually beginning with pyroclastic rocks, continuing with effusion of lavas and ending in a variety of volcaniclastic rocks. Epiclastic and volcanic sediments were deposited between episodic effusions. In the eastern part of the island, quite well-preserved paleovents occur (Fig. 18). A hypabyssal intrusion of albite granophyre crops out in the northeast sector of the island.

Four major groups of rocks are recognised on Seton Island.

(i) Volcaniclastic Rocks - The volcaniclastic rocks of Seton Island are reworked and primary tuffs, breccias and agglomerates. The pyroclastics are of two types namely: spilitic and quartz keratophyric.

The spilitic tuffs are green, massive to well-bedded and occur as units with an average thickness of 30 m. They are coarse- to fine-grained, and of lithic and vitric varieties. In

thin section, the lithic, spilitic tuffs contain 75-80% lithic clasts of chloritized spilitic lava and pumice, set randomly in a groundmass of carbonate, albite crystals and chloritized vitric shards.

The quartz keratophyric tuffs are usually coarse-grained, maroon-grey to pink in color, and well-bedded. They often possess sedimentary structures characteristic of shallow-water deposition. In thin section these tuffs commonly contain abundant albite pyroclasts (75-80% of the mode) and quartz (5-10% of the mode), set within a carbonate and devitrified glassy matrix. The albite occurs as tabular crystals exhibiting distinct 'chequer-board' twinning. A second generation of pellucid albite occurs as transecting veinlets.

Autoclastic breccias and agglomerates which occur within the sequence are usually composed of poorly-sorted fragments of porphyritic and amygdaloidal flow rocks with pyrogenic crystal clasts, set in a vitroclastic matrix of tuff and lapillistone.

(ii) Lavas - The Seton lavas consist of greyish-green, massive to columnar, porphyritic to amygdaloidal, spilitic basalt flows and flow breccias. They are characterized by the typical spilitic mineral assemblage of albite + chlorite + magnetite + ilmenite $\pm$ biotite, carbonate, quartz, sphene and hematite. Approximate modal percentages of the major mineral constituents are; albite 65-85%, chlorite 5-17%, magnetite and ilmenite 5-20%.

The texture of the lavas range from trachytic to felty, and intersertal to hyalopilitic. Amygdule minerals present

are quartz, carbonate, albite and chlorite. The phenocrysts range in composition from albite to sodic oligoclase.

Detailed petrographic descriptions of chemically analyzed Seton lavas are presented in Appendix D.

(iii) Sedimentary Rocks - Marine epiclastic- and volcanic-sandstones, siltstones and shales are interbedded with the volcanic rocks of Seton Island. The volcanic sandstones are usually moderately- to poorly-sorted and consist of quartz, 'chequer-board' albite and admixed epiclastic material, set in a groundmass of carbonate and chloritized glass dust.

The epiclastic sandstones, siltstone and shales are commonly red to pink in color, micaceous and well-sorted. They display sedimentary structures and occasionally contain gypsum casts, all of which suggest shallow, marine sedimentation. They are strikingly similar in lithologic features to the Akaitcho River and Kluziai Formations of the underlying Sosan Group.

(iv) Intrusions and Veins - A hypabyssal intrusion of pink, albite granophyre crops out in the northeast sector of Seton Island. In thin section, the rock is medium-grained and exhibits a distinct granophyric texture. Mymerkitic texture also occurs. The granophyre is dominantly composed of tabular or short prismatic crystals of twinned orthoclase and albite, which constitute about 80% of the rock. Quartz, which is prominently interstitial forms up to 15% of the mode. Euhedral sulfides and opaque iron-oxides constitute 3-4% of the rock, while green chlorite composes 1-2% of the mode.

Epidotite veins and patches occur rarely, within the upper lavas of the northern sector of the island. In thin section, the epidotite is fine-grained and consists mainly of pistacite (85% of the mode), albite (10% of the mode) and opaque sulfides and iron-oxides which constitute 5% of the rock. The highly birefringent pistacite occurs as prismatic to granular aggregates, varying in grain size from 0.3-0.8 mm. Pellucid albite which is definitely interstitial occurs as crystals of various shapes, and sometimes as transecting veinlets.

Toopon Lake

In the area around Toopon Lake, the Seton volcanics are some 250 m thick, and lie conformably upon the 15 m thick Akaitcho River Formation. In a few localities where the Seton Formation is missing, the Akaitcho River Formation is correspondingly thicker; a fact that suggests contemporaneous volcanism and marine sedimentation.

A basal unit of highly-altered, clayey, vitric, basic tuff and sheared lapillistone characterize the Seton Formation in the area. A 6 m thick sandstone bed occurs near the base of this unit. Overlying this altered basal unit are a 25 m thick, massive, amygdaloidal, spilitic basalt flow and a flow breccia. The flow consists of decussate laths of albitic-plagioclase, set in a groundmass of cryptocrystalline albite and chlorite. Small amygdules are present and are filled with penninite and pellucid albite.

A 40 m thick well-bedded, maroon, quartz keratophyric tuff, with admixed epiclastic material, overlies the lava flow. Overlying this tuff is a poorly-sorted, reworked, cross-bedded agglomerate and tuff-breccia. Cobbles and blocks of the amygdaloidal spilitic flow, accidental fragments of granite, iron formation and chloritized schist clasts, are poorly cemented in a carbonatized crystal tuff and lapillistone groundmass. This agglomerate unit has been previously observed in many parts of the East Arm (STOCKWELL, 1932; HOFFMAN, 1968) and may constitute a useful marker unit for future correlative purposes.

Above the reworked agglomerate, the remainder of the sequence is characterized by green, vitric and crystal tuffs, tuff-breccia and interbeds of micaceous siltstone.

Tuffisite dykes and cherty veins commonly occur within the sequence.

The Fort Reliance Area

East of Fairchild Point within the Fort Reliance area, a 40 m thick sequence of Seton volcanics conformably overlies the Akaitcho River Formation (OLADE, 1971b). It comprises green, spilitic, vitric tuffs, spilite and a trachytic flow. The trachytic flow is highly vesicular and commonly porphyritic. It is deep-pink or maroon in color and composed of altered alkali feldspar, set in a microcrystalline matrix of feldspar, carbonate and opaque minerals. The amygdules are filled with quartz and carbonate. Disseminations of iron- and copper-sulfides are

common within this latter rock type.

The occurrence of the Seton Formation in the NE extremity of the East Arm fold belt contradicts HOFFMAN's (1968, 1969) earlier supposition that the Seton volcanics do not crop out within the eastern half of the East Arm region.

Stratigraphic Correlation

A stratigraphic correlation between the Seton Formation at Seton Island, Toopon Lake and the Fort Reliance area is presented in Figure 19. The recurrence of lithologies, lateral facies change and faulting, and the fact that the Formation thickens towards the SW make the correlation tentative.

Between Toopon Lake and Seton Island, the unit of reworked agglomerate constitutes a useful marker horizon for correlative purposes. The Akaitcho River Formation is absent in the Seton Island section and this may be due to lateral facies change. A distinct unit of micaceous sandstone which occurs within the lower part of the Seton Formation on Seton Island is correlated with the micaceous sandstone of the Upper Member of the Kluziai Formation at Toopon Lake.

The stratigraphic section of the Seton Formation exposed within the Fort Reliance area is not complete because of erosion. The only definitely correlative unit between this area and Toopon Lake is the spilitic lava flow.

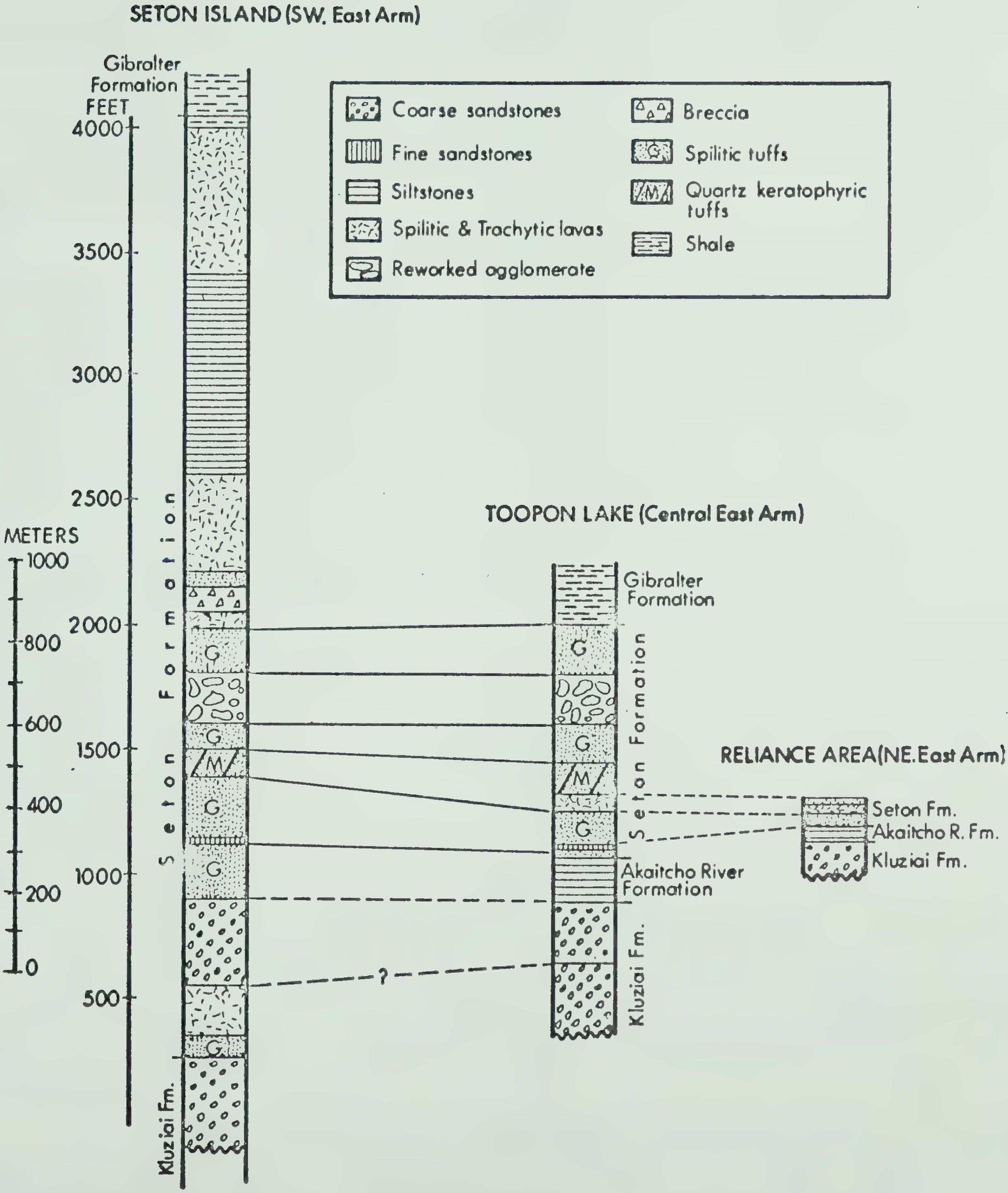


FIGURE 19: Tentative Correlation Between the Seton Formation at Toopon Lake, the Reliance Area and Seton Island

Petrochemistry of the Lavas

Chemical analyses of fifteen lavas from Seton Island are presented in Table 5. CIPW norms (Table 6) were calculated on an H_2O- and CO_2-free basis by an APL computer program (CIPWNORM). The analytical methods employed are summarized in Appendix B and Appendix C.

Compared with the average basalt (MANSON, 1968) shown in Table 5, the Seton volcanic flows are somewhat enriched in Fe, TiO_2, Na_2O, K_2O, and somewhat deficient in CaO, MgO and Al_2O_3. The AFM diagram (Fig. 20) for the Seton lavas shows a concentration of data towards the Alk-Fe side of the diagram.

The relatively high Na_2O content of the lavas clearly reflects the sodic composition of the plagioclase, and the MgO variations are attributable to the obvious variation in the amount of chlorite in the groundmass. The relative abundances of magnetite and ilmenite (which often constitute more than 10% of the mode) correlate respectively with the high Fe and TiO_2 concentrations encountered.

The rather high K_2O content of samples SET-9 to -12, -18, and -19 is probably due to the presence of K-feldspar which is difficult to distinguish from the poorly twinned, fine-grained albitic-plagioclase.

The variable CaO content reflects almost entirely a variation in the degree of carbonate replacement and minor veining observed in hand specimen.

A detailed petrographic description of each analyzed

TABLE 5

PARTIAL CHEMICAL ANALYSIS OF SETON SPILITIC ROCKS

	SPILITES											POTASH SPILITES				AVERAGE** SPILITE	AVERAGE*** SPILITE
SAMPLE NO	SET 1	SET 6	SET 7	SET 8	SET 9	SET 10	SET 14A	SET 14	SET 15	SET 16	SET 17	SET* 11	SET 12	SET 18	SET 19		
SiO_2	49.3	48.7	47.3	54.6	50.7	50.8	52.1	50.9	51.3	51.8	53.6	63.9	51.1	50.5	52.8	51.2	49.3
TiO_2	2.3	2.8	2.6	2.0	2.4	2.6	2.8	3.4	2.8	1.6	1.5	1.6	2.8	2.2	2.1	3.3	2.0
Al_2O_3	14.9	14.6	14.6	14.5	14.9	14.4	14.3	14.3	15.0	14.1	14.3	12.4	14.1	16.6	14.5	13.7	16.0
Fe_2O_3	3.8	4.3	4.1	3.4	3.9	4.0	4.3	4.9	4.3	3.1	3.0	3.1	4.3	3.7	3.6	2.8	3.2
FeO	9.9	12.2	11.3	8.7	10.9	10.1	10.4	10.6	11.9	11.7	11.8	10.7	9.5	11.3	10.4	9.2	7.8
MgO	5.4	4.4	5.6	1.8	4.4	5.0	3.4	6.5	4.9	3.1	5.1	1.5	4.9	3.5	3.5	4.6	6.6
CaO	4.0	4.5	6.4	4.2	3.1	3.9	2.9	2.1	3.4	5.9	3.1	0.8	2.4	4.3	3.7	6.9	9.9
Na_2O	3.5	5.4	5.1	7.5	3.4	5.2	5.7	4.1	4.0	4.1	2.7	1.6	2.8	2.8	2.3	4.9	2.9
K_2O	1.2	0.3	0.4	0.8	1.7	0.8	1.0	1.4	0.4	2.9	0.9	3.2	3.3	3.5	3.7	0.8	1.0
H_2O^+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9	0.9
H_2O^-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
PARTIAL TOTAL	94.3	97.2	97.8	97.5	95.4	96.8	96.9	98.2	98.0	98.3	96.0	99.0	95.2	98.4	96.6	99.2	99.6

* Highly vesicular spilite (with quartz filled amygdules). Analyses not plotted on all variation diagrams

** Sundius' average spilite (1930)

*** Average basalt (Manson, 1968)

TABLE 6

NORMATIVE COMPOSITION OF SETON SPILITIC ROCKS

	SPILITES											POTASH SPILITES			
SAMPLE No	SET 1	SET 6	SET 7	SET 8	SET 9	SET 10	SET 14A	SET 14	SET 15	SET 16	SET 17	SET 11	SET 12	SET 18	SET 19
Q	0.90	-	-	-	10.68	1.17	2.73	5.87	10.51	-	15.45	32.23	10.62	0.63	9.05
Or	7.80	7.37	2.48	3.78	10.85	4.72	6.14	8.56	2.61	17.78	5.61	19.15	21.18	21.27	22.93
Ab	32.50	40.41	35.21	65.84	31.86	46.54	50.86	36.30	35.73	36.05	24.02	13.70	25.70	24.62	20.13
Ar	20.39	9.69	13.44	4.29	6.12	9.67	9.82	5.90	10.91	11.99	11.16	4.11	7.64	21.97	18.89
Ne	-	3.85	5.22	0.04	-	-	-	-	-	-	-	-	-	-	-
Ol	-	15.17	16.10	5.48	-	-	-	-	-	5.97	-	-	-	-	-
Hy	16.70	-	-	-	23.61	24.93	17.82	26.15	24.69	13.77	30.89	18.18	18.84	21.18	19.45
Di	0.94	11.39	16.34	15.06	-	-	-	-	-	6.66	-	-	-	-	0.09
Mt	6.02	6.51	6.13	3.65	6.11	6.14	6.54	6.93	6.59	4.64	4.59	4.61	6.72	5.52	5.36
Il	4.75	5.58	5.07	1.84	4.88	5.01	5.56	6.09	5.63	3.12	3.01	3.15	5.71	4.27	4.08
C	-	-	-	-	5.86	1.80	0.49	4.17	3.31	-	5.23	4.83	3.55	0.52	-

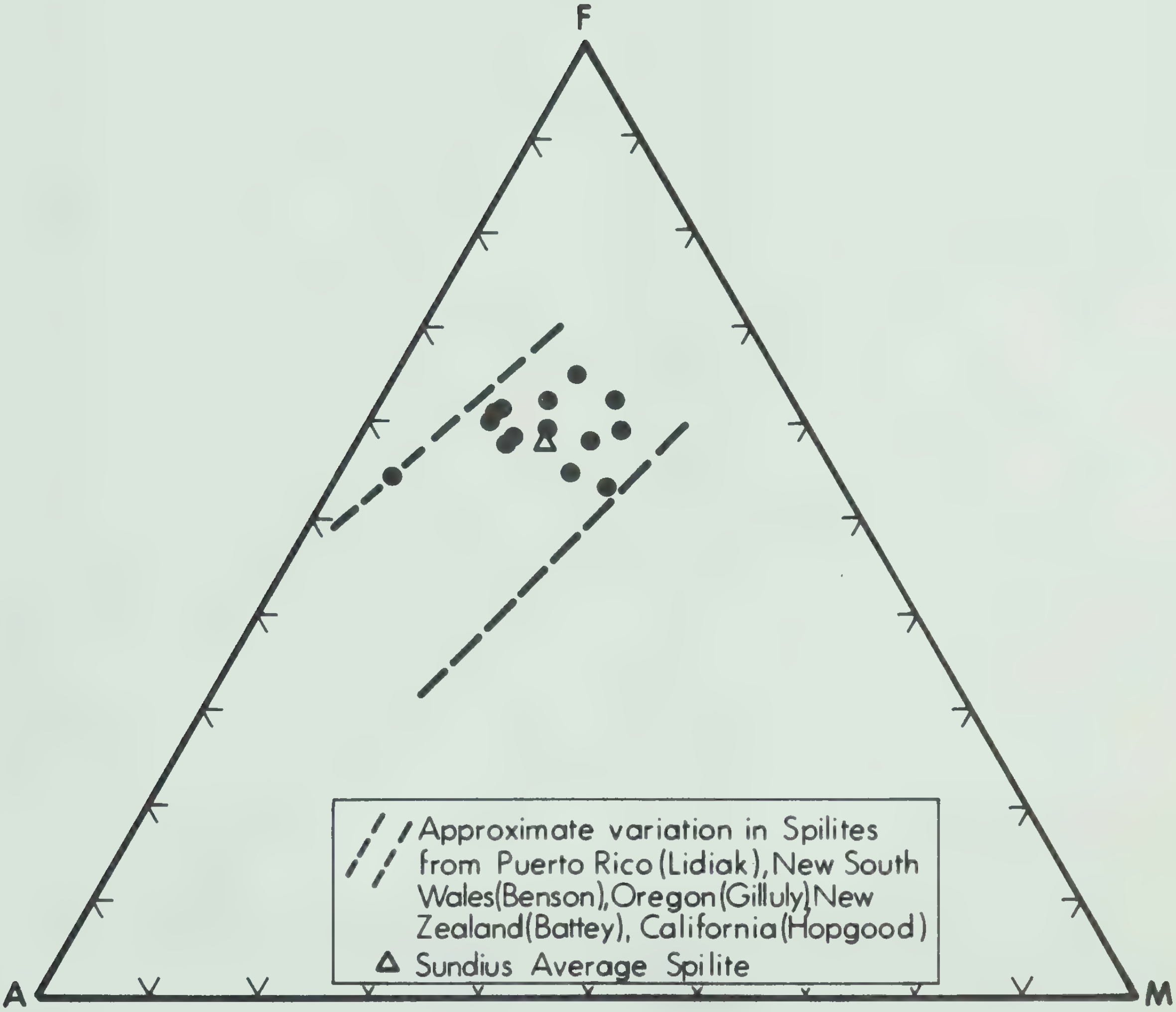


FIGURE 20: A.F.M. Diagram for Volcanic Rocks, Seton Island. N.W.T.
(A= Na_2O+K_2O ; F= $FeO+0{\cdot}8998\ Fe_2O_3$; M= MgO, all in wt.%)

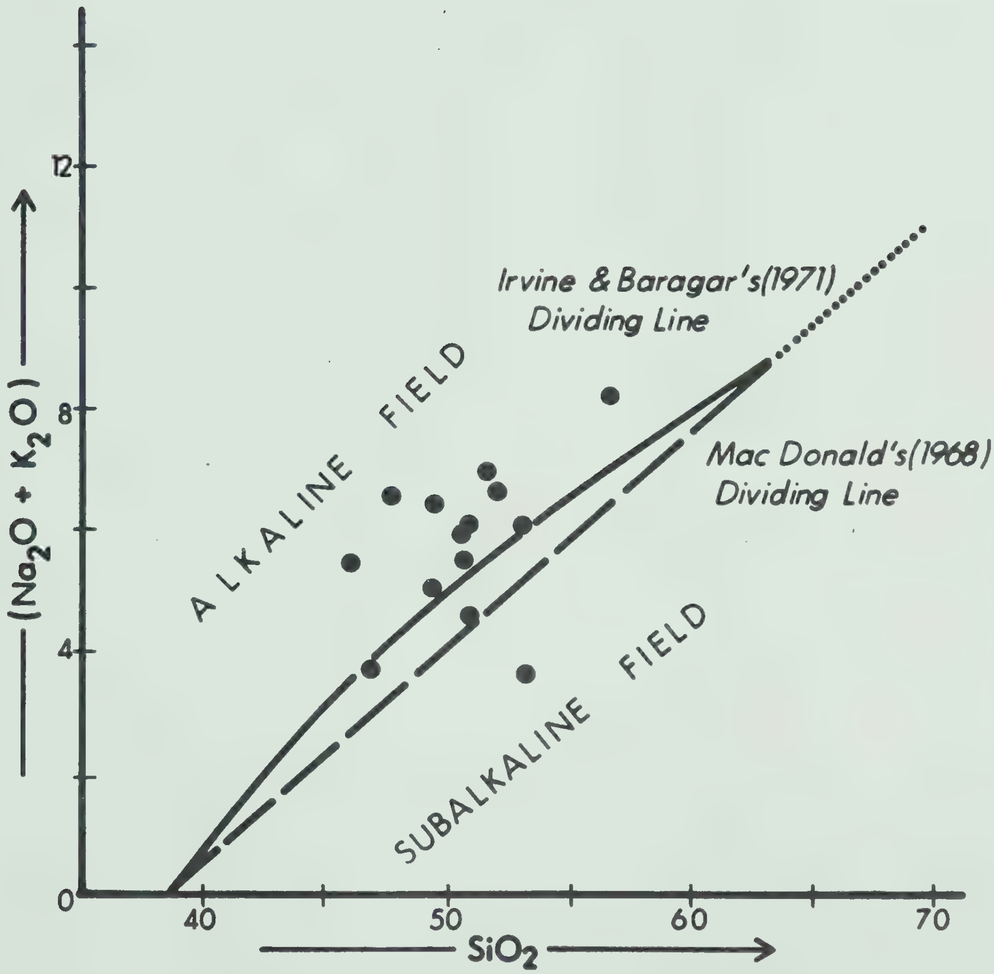


FIGURE 21 : Alkalies-Silica Diagram for the Seton Island Volcanic Rocks (Plots in wt.%)

sample is presented in Appendix D.

Classification of the Volcanic Suite

Chemical Classification

A plot of the chemical analyses for the lavas on an alkalies-silica diagram (Fig. 21) suggests that they possess distinct affinities with the transitional and alkali basalts. Employing the divisional line proposed by IRVINE and BARAGAR (1971), only two of the rock samples SET-17 then falls within the Sub-alkaline field. To determine whether the Seton alkali lavas belong to the 'sodic' or 'potassic' series (IRVINE and BARAGAR, 1971) of the alkali basalts, a plot of normative An-Ab'-Or was prepared (Fig. 22). The diagram shows that four of the rock samples; SET-11, SET-12, SET-18 and SET-19, were distinct in that they fall into the field of the 'potassic' series, while the rest of the samples belong to the 'sodic' series. This fact has been used in differentiating the Na-spilites from K-spilites. Figure 23 presents the alkali ratios for the Seton volcanic rocks. This diagram suggests that a possible inverse relationship exists between the K_2O and Na_2O concentrations observed in the lavas.

The Spilitic Affinity of the Volcanic Suite

The characteristic assemblage of albite + chlorite + iron oxides $\pm$ carbonate, biotite and quartz in the lavas, together with the high Na_2O and H_2O content indicate a spilitic affinity

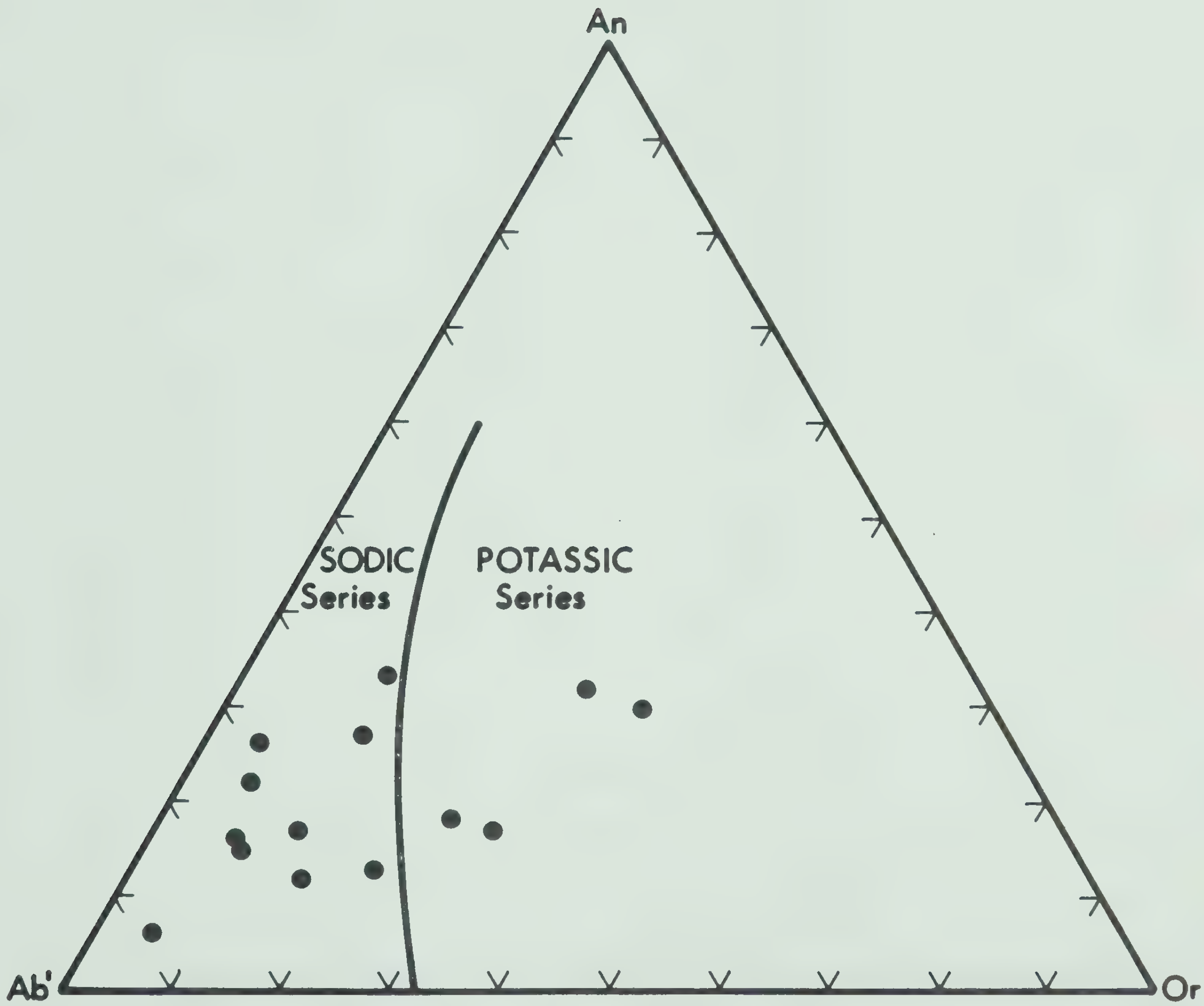


FIGURE 22: An - Ab' - Or Projections for Volcanic Rocks, Seton Isl., N.W.T.
(Dividing Line is that proposed by Irving & Baragar, (1971).)

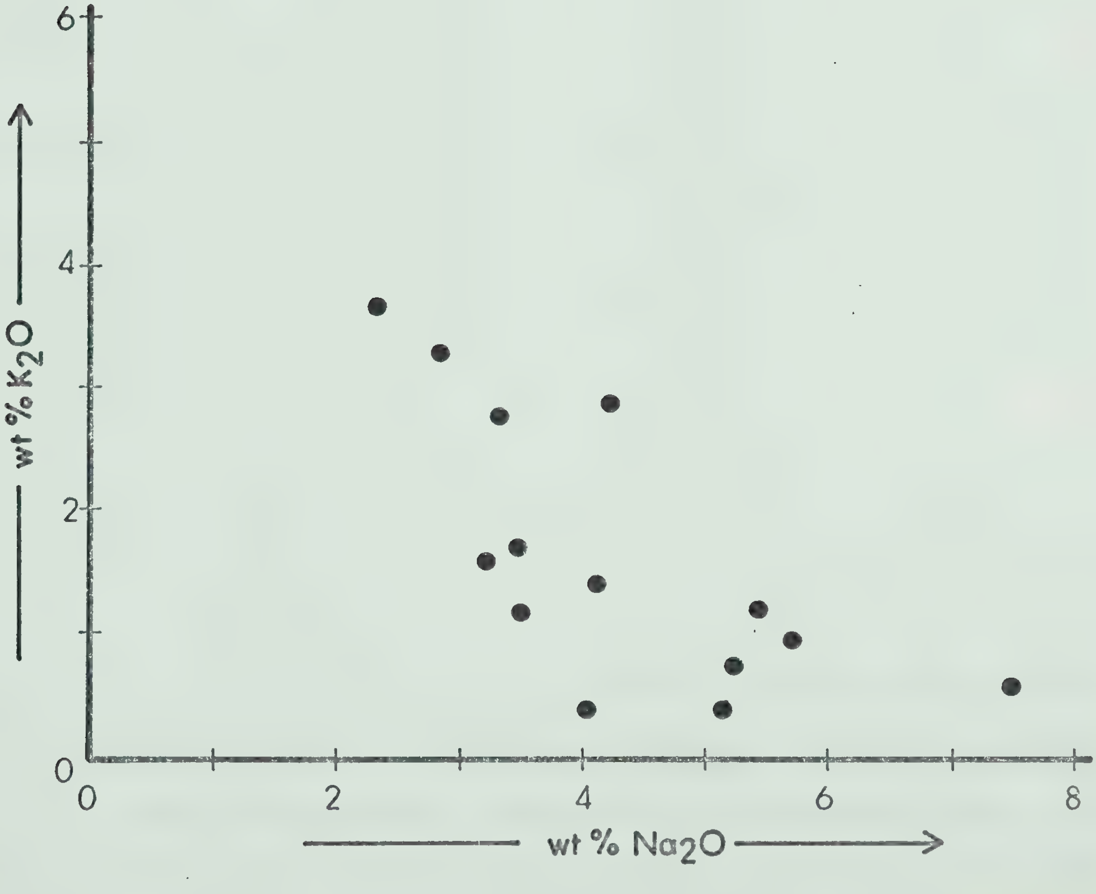


FIGURE 23: Alkali Ratios for Volcanic Rocks, Seton Island. East Arm of Great Slave Lake, N. W. T.

for the extrusive suite as defined by SUNDIUS (1930). However, the Seton spilites are somewhat depleted in CaO compared with SUNDIUS' (op. cit.) average spilite; a fact which might be explained by a bulk loss of Ca during 'spilitization'. The fate of this lost Ca might be in part explained by the presence of epidotite (albite + pistacite + Fe-oxides) veins which occasionally occur in the upper lavas at the north end of Seton Island. Such a case would be directly analogous with the Ca migration during spilite genesis suggested by AMSTUTZ (1968).

Those members of the volcanic suite having a notably higher K_2O content (SET-, 11,12,18 and 19) are classified as K-spilites; this term being preferred, rather than 'weillburgite' (LEHMANN 1941, 1952) or 'poenite' (DE ROEVER, 1942). AFM and Ca:Na:K variation diagrams for the Seton spilitic suite are compared in Figures 20 and 24 with spilites from Puerto Rico (LIDIAK, 1965), New South Wales (BENSON, 1915), Oregon (GILLULY, 1935), New Zealand (BATTEY, 1956) and California (HOPGOOD, 1962).

During this investigation, no truly keratophyric lavas were recognized. However, as is common in such spilitic suites, evidence of explosive keratophyric volcanic activity is abundant in the form of keratophyric tuffs (MORTON and SMITH, 1971). It is pertinent at this juncture to mention that HOFFMAN (1968, 1969) has noted the occurrence of 'rhyolites' in this sequence elsewhere in the East Arm (Keith Island), which might well be quartz keratophyres related to the Seton Island suite.

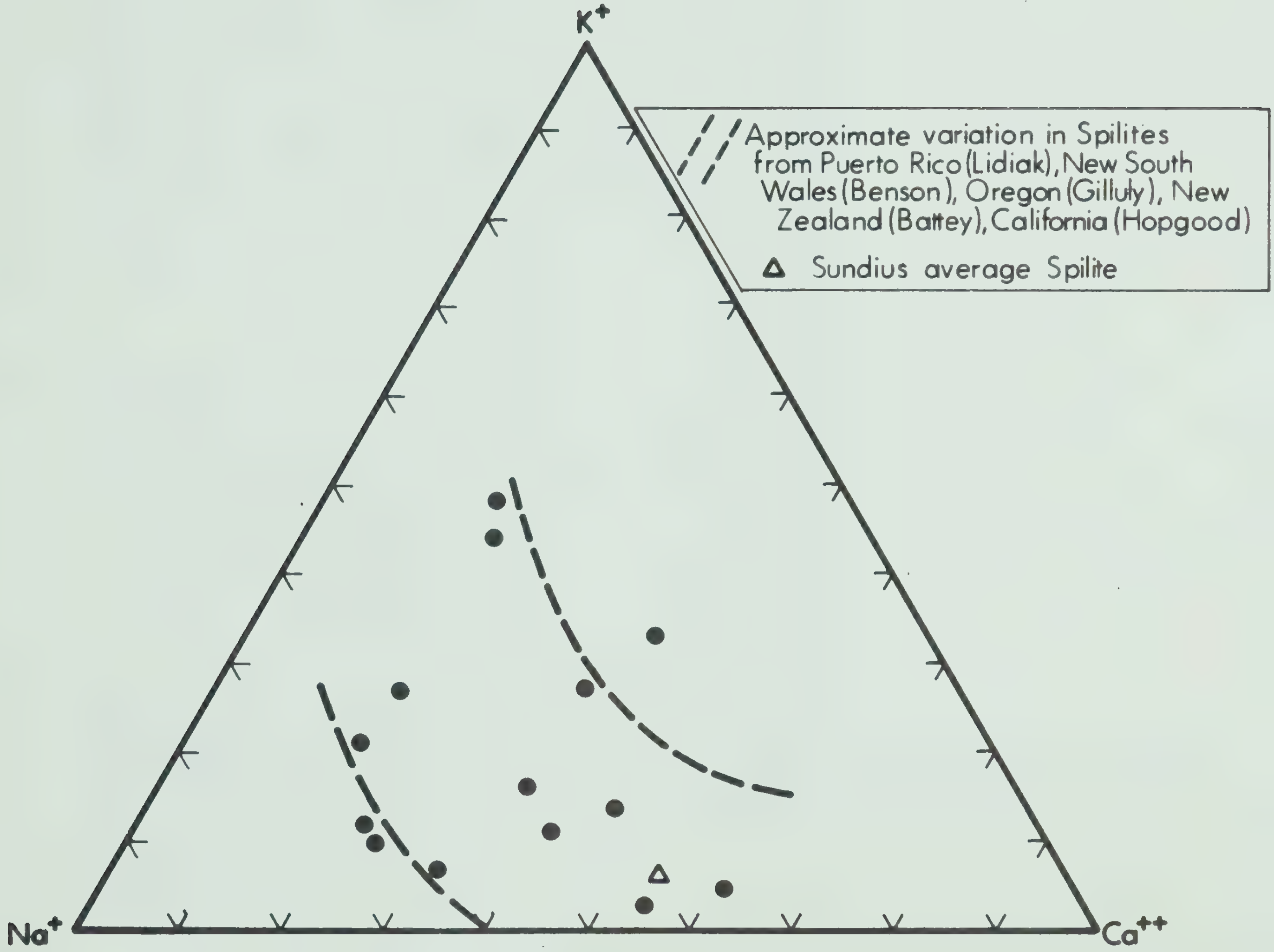


FIGURE 24: Ca : Na : K Variation of Volcanic Rocks, Seton Island. N.W.T.

Conclusions

The Proterozoic Seton Formation which has earlier been described as greenstones, basalts and recently as an andesite-rhyolite suite, has now been proved to contain evidence of spilitic (basaltic) vulcanicity. Contrary to recent observations, (HOFFMAN, 1969) this volcanism affected almost the entire East Arm sector of the Coronation geosyncline during early Proterozoic times.

The Seton volcanism was obviously associated with a small volcanic island complex which was in part submarine. The apparent contemporaneity between the Seton vulcanicity and the deposition of the upper members of the Sosan Group (Kluziai and Akaitcho River Formations) is evidenced by lateral facies changes associated with island volcano environments (Fig. 25.). This fact clearly suggests that the Seton Formation should be re-classified into the Sosan Group rather than the Kahochella Group. This is in many ways compatible with the correlative diagrams of HOFFMAN (1968).

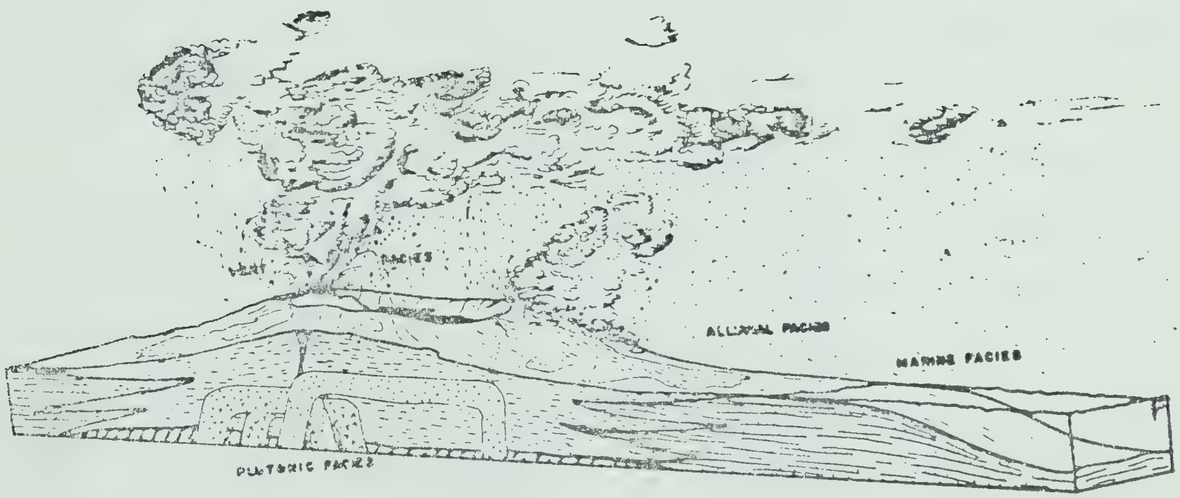


FIGURE 25: A schematic reconstruction showing penecontemporaneous rock facies associated with island volcano environments. (After HUGHES and BRUCKNER, 1971)

CHAPTER SEVEN

SUMMARY AND CONCLUSIONS

The Lower Aphebian rocks exposed within the area south of McLean Bay in the central part of the East Arm of Great Slave Lake, comprise a thick succession of sedimentary and volcanic rocks belonging to the Sosan and Kahochella Groups. Geologic mapping and stratigraphic studies show that the lowest lithostratigraphic unit in the area is the Duhamel Formation, which consists of a cyclic dolomite-sandstone sequence deposited in a slowly-subsiding tidal platform.

The Kluziai Formation which hosts the 'sandstone-type' uranium mineralization in the Toopon Lake area conformably overlies the Duhamel Formation. During this investigation, the Kluziai Formation has been subdivided into three distinct Members which are mappable and can be traced throughout the central part of the East Arm region. Paleocurrent, provenance and paleoenvironmental studies suggest that the sandstones and conglomerates which constitute this formation were deposited by a complex system of WSW-flowing, braided streams that derived their sedimentary material from a predominantly plutonic terraine to the NE of the region, where presently exposed are Kenoran catazonic granites and metamorphics. A thick, monotonous sequence of deltaic, glauconitic red beds of the Akaitcho River Formation conformably succeed the Kluziai Formation. The lateral and vertical extent of these red

beds and the occurrence of authigenic glauconite (indicating a high ferric:ferrous ratio) suggest that when these rocks were deposited the Precambrian atmosphere must have been oxygenic. A Rb-Sr and/or K-Ar dating of the glauconite is recommended, and any age obtained may be cross-checked by dating the Seton volcanics which are stratigraphically equivalent to the Akaitcho River Formation. Also, it may possibly shed some light on the supposed diffusion of Ar and Sr in old and unmetamorphosed glauconites.

The Seton volcanics which overlie, and are in places stratigraphically equivalent to the Akaitcho River and Kluziai Formations, constitute a somewhat stratigraphically complex unit within the Proterozoic sequence of the region. Petrochemical and petrographic studies suggest that the volcanic rocks of the Seton Formation which have earlier been described as greenstones or basalts and recently as an andesite-rhyolite suite, obviously possess a spilitic-keratophyric affinity. Associated with the Seton alkali volcanism are hypabyssal intrusions of albite granophyre and subvolcanic quartz-feldspar porphyries. The spilitization process is tentatively envisaged as a syn- to post-consolidation alkali metasomatism which produced a Na^+ and K^+ replacement of the Ca-plagioclase feldspars and a subsequent migration of Ca^{++} and other elements to form patches and veins of epidotite. Geological mapping in the East Arm has also revealed that the Seton Formation is more widely distributed than earlier conceived, and any tectonic significance attributed to its supposed restriction to the SW of the region may not be relevant. Rock facies variations associated

with island volcano environments (HUGHES and BRUCKNER, 1971) occur on Seton Island, and these suggest that the Seton vulcanicity, which in the SW of the region was associated with an ancient volcanic island complex, was contemporaneous with shallow marine sedimentation (Akaitcho River Formation) towards the NE. This evidence and other stratigraphic reasons suggest that the Seton Formation should be re-classified into the Sosan Group.

Structurally, the Lower Aphebian rocks in the Toopon Lake area are gently to complexly deformed around northeasterly trending axes. Folding is distinctly disharmonic, as a result of the varying structural competence of the deformed lithostratigraphic units.

Peneconcordant 'sandstone-type' uranium mineralization analogous in certain aspects to the Wyoming- and Colorado-type uranium deposits occur within the fluvial sandstones of the Kluziai Formation in the Toopon Lake area. Similar occurrences, although in conglomerates and conglomeratic sandstones, have been reported from Simpson Islands and Fort Reliance area of the East Arm of Great Slave Lake. A mineral assemblage of pitchblende-graphite-pyrite-chalcopyrite characterizes the uranium mineralization. A genetic model, in which uranium and other metals were leached from the spilitized Seton volcanic debris during diagenesis and subsequently deposited in porous well-sorted, braided-channel deposits as a result of changes in Eh and/or pH, is postulated for the Toopon Lake uranium occurrences.

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APPENDIX A

DESCRIPTIONS OF STRATIGRAPHIC SECTIONS, TOOPON LAKE

Unit	Lithology	Approx. Thickness
	Akaitcho River Formation	
8	Shale, red, micaceous, laminated, recessive.	10'
7	Siltstone, red, glauconitic, micaceous, thin-bedded, with intercalated beds of red, laminated shales.	130'
6	Siltstone, red, micaceous, flaggy with interbedded, thin, green, glauconitic, sericitic siltstone beds.	250'
5	Siltstone, red, micaceous, glauconitic, medium- to thin-bedded, mud-cracked, simple cross-bedding and current lineations.	400'
4	Sandstone,fine-grained, red, micaceous, thin- to medium-bedded, flame structures, and ripple marks.	4'
3	Sandstone, fine-grained, buff, with interbedded red micaceous sandstone. Uniform, medium- to thin-bedding.	1'
2	Orthoquartzite, white to buff, medium- to fine-grained, well-sorted, medium- and evenly-bedded, cross-bedded.	30'
1	Siltstone, red, micaceous, glauconitic, thin-bedded, mud-cracks, current lineations.	1'

Unit	Lithology	Approx. Thickness
	Seton Formation	
10	Tuff, green, basaltic, massive, vitric and lithic, medium- to fine-grained; minor tuff-breccias.	220'+
9	Agglomerate, reworked brown-weathering, friable, thick-bedded, cross-bedded, poorly sorted, angular to subrounded fragments of granite, iron formation, amygdaloidal spilite, cherty nodules, set in matrix of crystal tuff and lapillistone; minor reworked tuff.	130'
8	Agglomerate, medium- to thick-bedded, well-cemented, angular to rounded fragments of porphyritic spilitic flow, tuff, iron formation and chloritized schist clasts.	60'
7	Tuff, green, spilitic, vitric, medium- to thick-bedded; minor tuff-breccia.	150'
6	Tuff, maroon, well-bedded quartz keratophyric, admixed epiclastic quartz, microcline; minor volcanic sandstone and reworked lapillistone.	120'
5	Basalt, spilitic, greyish-green, amygdaloidal, massive to columnar; minor flow breccia.	70'
4	Tuff, green, basaltic, lithic, massive to thick-bedded.	95'
3	Lapillistone, greenish-white, sheared, clayey?, carbonatized, medium- to thick-bedded.	20'
2	Sandstone, buff to pink, fine-grained, tuffaceous, medium-bedded.	16'
1	Tuff, whitish-green, highly altered, clayey?, medium- to thick-bedded, poorly cemented; minor lapillistone.	35'

APPENDIX B

X-RAY SPECTROGRAPHIC ANALYSIS

Introduction

Fifteen rock samples of the Seton volcanic rocks were analyzed by an X-ray spectrographic technique, utilizing a heavy absorber matrix (fusion method), as suggested by NORRISH and HUTTON (1969), but, with minor modifications.

The most obvious advantage of the fusion method is that it normalizes matrix effects through a process of sample dilution, with the addition of a heavy absorber. This results in a homogenous, reproduceable, resilient glass disc which displays a constant, linear relationship between element concentration and fluorescent intensity. Minor disadvantages of this method are the time-consuming procedure and the decrease in peak intensities.

Sample Preparation

In preparing the flux, about 38 g of anhydrous $Li_2O.2B_2O_3$, 30 g Li_2CO_3 and 13 g La_2O_3 (enough for 30 samples) were fused in a big platinum dish at 1000°C for 15 minutes. Prior to the fusion, La_2O_3 and the two lithium salts were dehydrated by heating at 900°C and 550°C respectively. The melt obtained during the fusion was poured on to a large polished aluminum sheet (> 3 mm thick), and after cooling, was crushed and ground into powder, and stored.

Each specimen was prepared by fusing 2 g of flux and 0.36 g of sample powder in a platinum-gold crucible at about 1000°C for 10 minutes, using a Meeker burner. An attempt was made to maintain a constant temperature of fusion, as lack of this can produce variations in fluorescent intensities. A graphite disc with a slightly concave upper surface and aluminum plunger (see NORRISH and HUTTON (op. cit.) for design) were placed on a hot plate at about 250°C. Immediately before pouring, the melt was thoroughly mixed and a brass ring was placed on the graphite disc. The melt was then poured into the centre of the disc, and immediately the plunger was brought down on to the melt. The plunger and brass ring were then withdrawn, and the glass disc was placed between folded aluminum foil and placed on another hot plate at 200°C. After 10 minutes or so, the foil was removed from the hot plate and the disc allowed to cool slowly. After cooling, the glass disc was stored in a labelled small envelope.

Analytical Determinations

Analytical determinations were made using the Philips Norelco X-ray Spectrographic equipment (unit type 12215/0) of the University of Alberta. Complete operating conditions are presented in Table 7.

Drift corrections were effected by bracketing every three samples between a standard. The observed drift was distributed by appropriate increments to each sample. Figures 26 to 31 present the working curves calibrated from U.S.G.S. - and other -

TABLE 7

Operating conditions for X-ray spectrographic analysis

ELEMENT	'TARGET'	PEAK (2)	B.G-1 (2)	B.G-2 (2)	F.T (sec)	XTAL	CTR	CTRV (volt)	X-RP	PHA	PHLV	PHW
Si	Cr	78.4	76.3	80.3	20	EDDT	F.P	1540	Vac.	Diff.	02.5	06.3
Ti	Cr	6.45	5.5	6.6	10	EDDT	F.P.	1580	Vac.	Diff.	20.0	10.0
Al	Cr	113.1	111.7	115.5	10	EDDT	F.P	1500	Vac.	Diff.	02.5	03.3
Ca	Cr	113.0	112.8	114.0	10	LiF	Scint.	1000	Vac.	Diff.	08.8	06.2
Mg	Cr	106.9	105.7	108.7	20	ADP	F.P	1640	Vac.	Diff.	14.2	08.3
Fe	W	57.57	56.3	59.3	10	LiF	Scint.	856	Air	Diff.	04.6	00.4

Explanation of Abbreviations.

B.G-1 - First background position in 2
B.G-2 - Second background position in 2
F.T - Fixed Time used in counting
XTAL - Analyzing Crystal
EDDT - Ethylene-Diamine-d-Tartrate
LiF - Lithium Fluoride
ADP - Ammonium Dihydrogen Phosphate
CTR - Counter (X-ray detector)

F.P. - Flow Proportional Counter
Scint. - Scintillation
CTRV - Counter Voltage
X-RP - X-ray Path
Vac. - Vacuum
PHA - Pulse Height Analyser
PHLV - Pulse Height Level Voltage
PHW - Pulse Height Width Voltage
Diff. - Differential (PHW engaged)

standards. Analyses of all standard rocks used are presented in Table 8.

The concentrations of the various elements in the analyzed samples were computed from the calibration curves. Fe_2O_3 was calculated from total Fe by assuming that $\%Fe_2O_3 = \%TiO_2 + 1.5$ (IRVINE and BARAGAR, 1971).

Replicate analyses of the samples within a month's interval, suggest that notable errors may occur only in the values obtained for MgO and SiO_2. Estimated precisions for MgO is $\pm$ 1.5%, for CaO, TiO_2 ($\pm$ 1%), while for Fe and Al_2O_3, $\pm$ 0.5-1%. For SiO_2 the estimated precision is $\pm$ 2%.

TABLE 8

Chemical analyses of standard rocks

	G-2	GSP-1	AGV-1	BCR-1	W-1	R-1	R-8	PCC-1	DTS-1
SiO_2	69.22	67.22	59.00	54.10	52.55	53.14	43.14	41.92	40.55
TiO_2	0.47	0.66	1.05	2.25	1.08	1.92	4.55	0.01	0.00
Al_2O_3	15.42	15.35	17.10	13.70	14.98	14.24	12.92	0.77	0.31
Fe_2O_3	1.01	1.64	4.35	3.24	1.41	1.10	1.73	2.72	0.98
FeO	1.49	2.34	2.07	9.07	8.71	8.47	12.34	4.93	6.93
MnO	0.04	0.05	0.10	0.19	0.16	0.19	0.25	0.12	0.12
MgO	0.76	0.99	1.50	3.47	6.59	2.24	5.42	43.35	49.85
CaO	1.98	2.07	4.89	6.91	10.98	4.33	8.90	0.40	0.03
Na_2O	4.05	2.79	4.23	3.26	2.14	4.84	3.41	0.00	0.05
K_2O	4.46	5.50	2.87	1.69	0.62	2.10	1.10	0.01	0.01
P_2O_5	0.13	0.28	0.49	0.35	0.12	1.00	1.82	0.00	0.00
H_2O	0.65	0.69	2.15	1.74	0.59	3.11	3.68	5.21	0.43

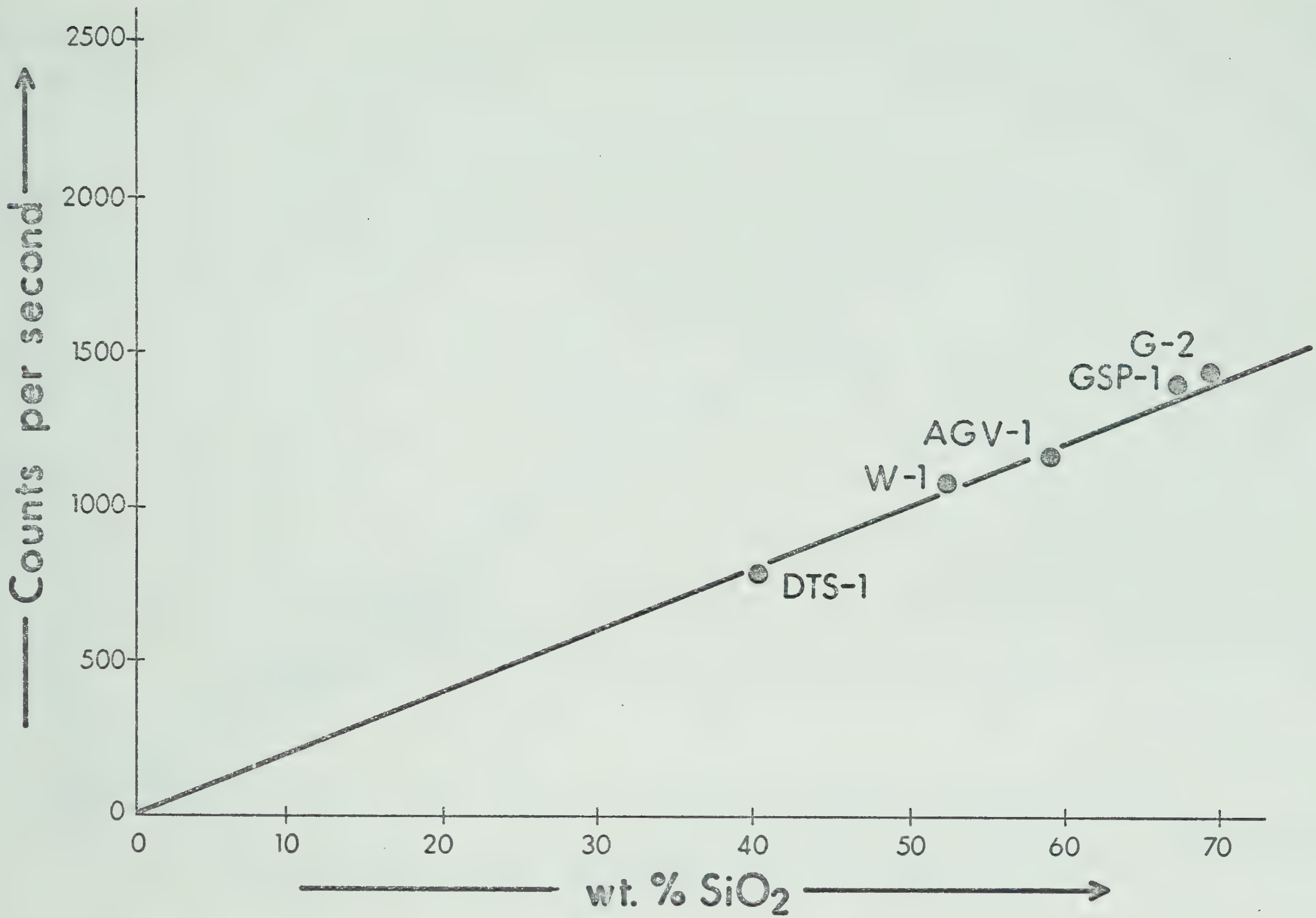

Fig.26: Calibration curve for SiO_2

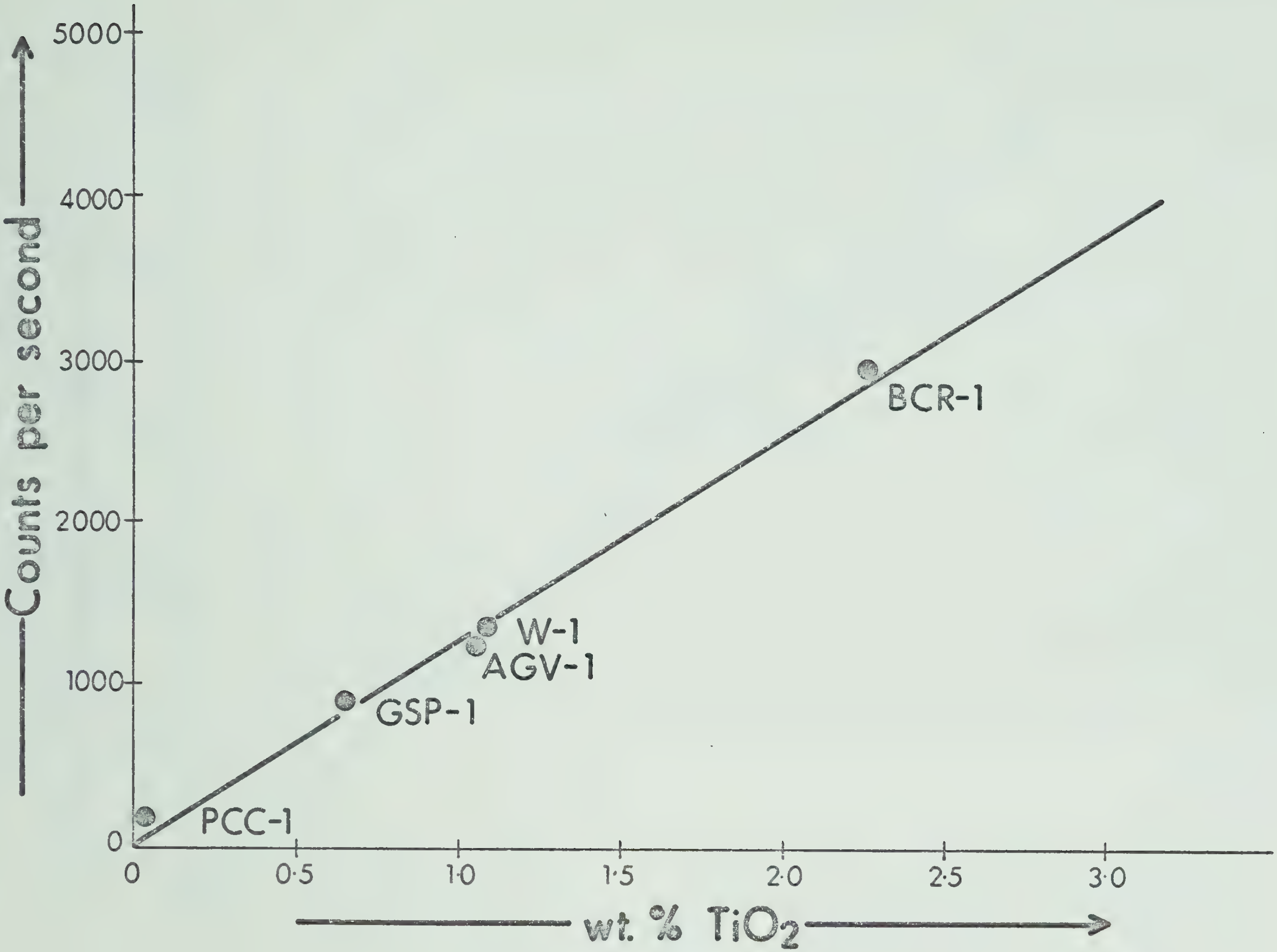

Fig.27: Calibration curve for TiO_2

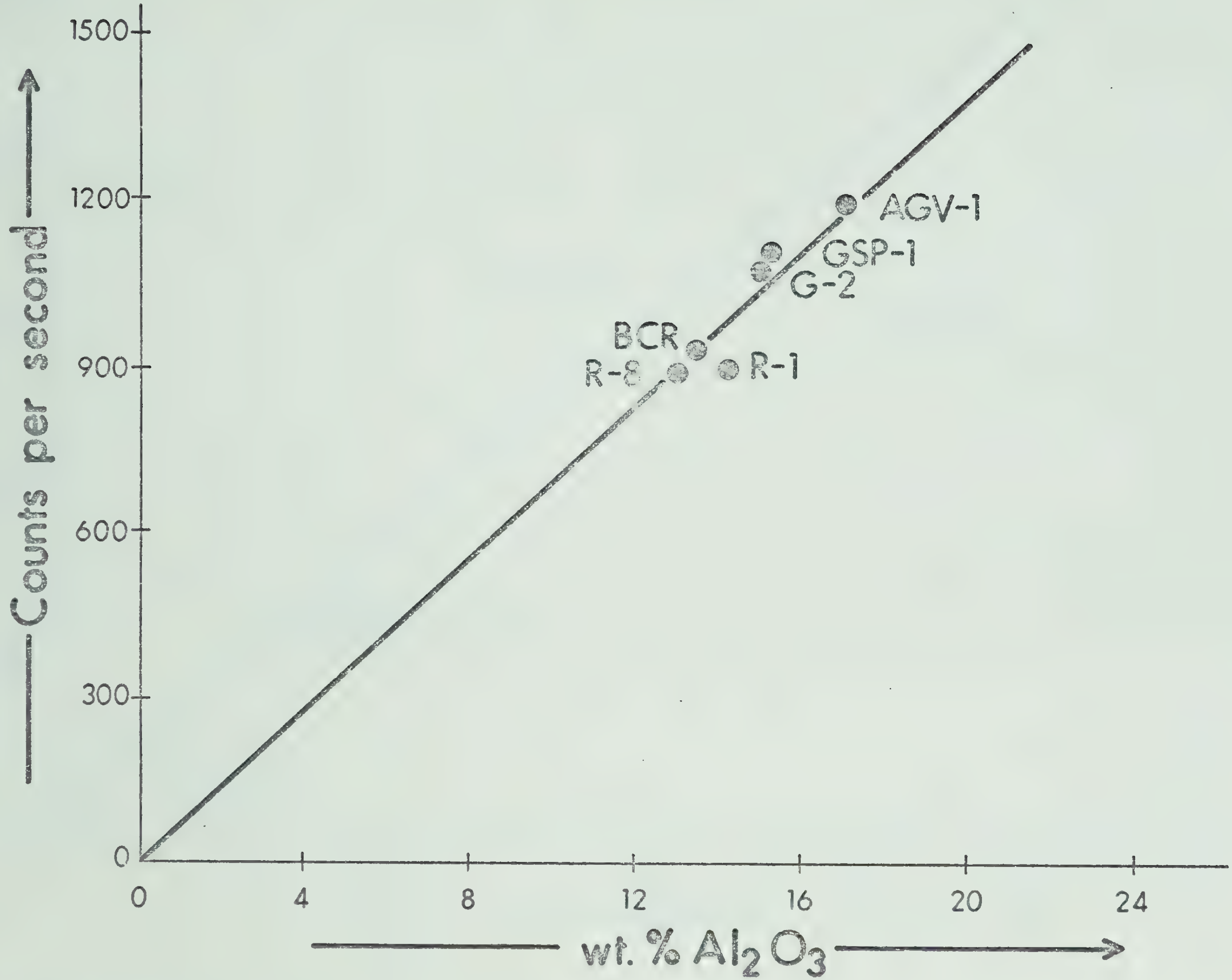

Fig.28: Calibration curve for Al_2O_3

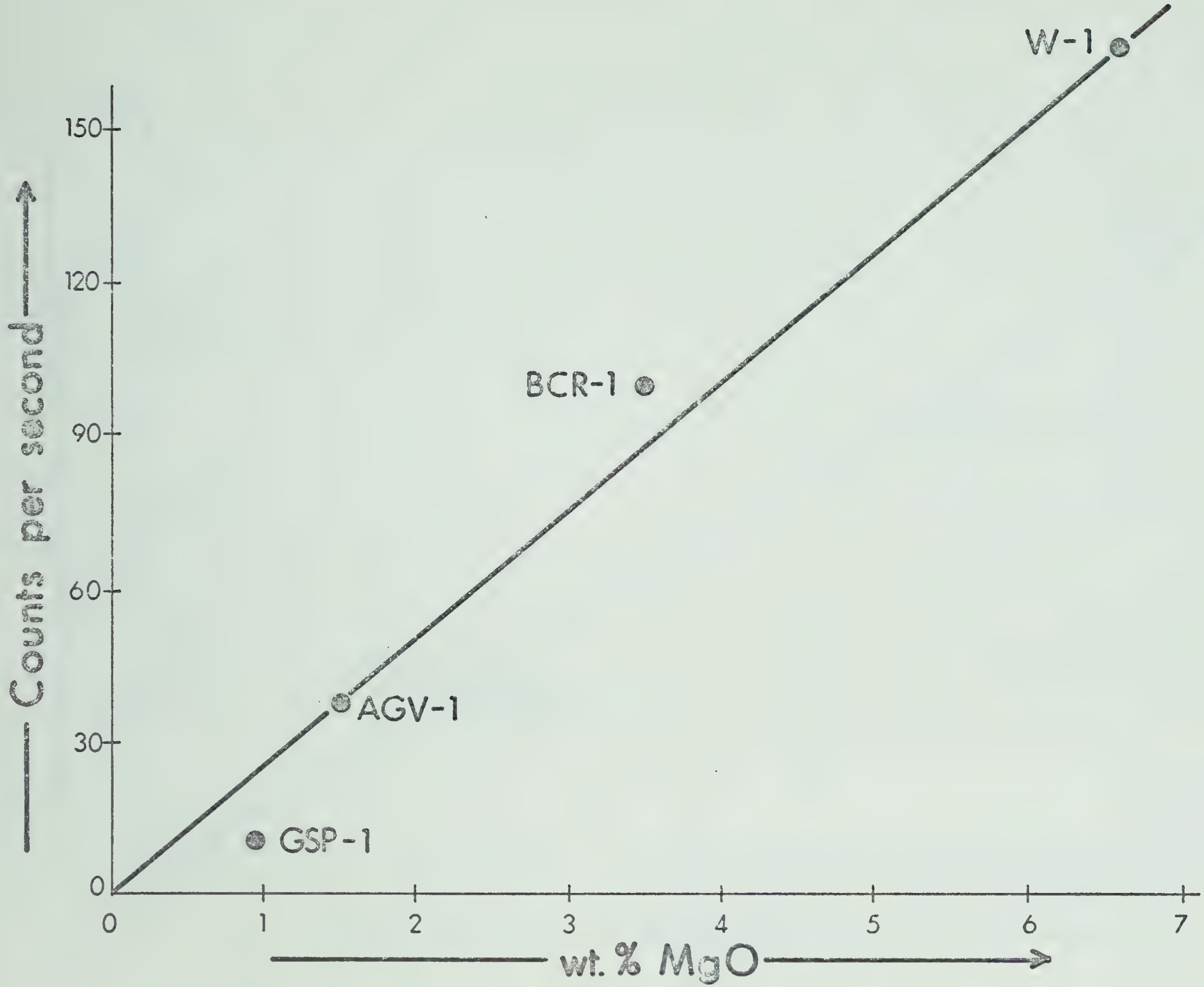

Fig.29 : Calibration curve for MgO

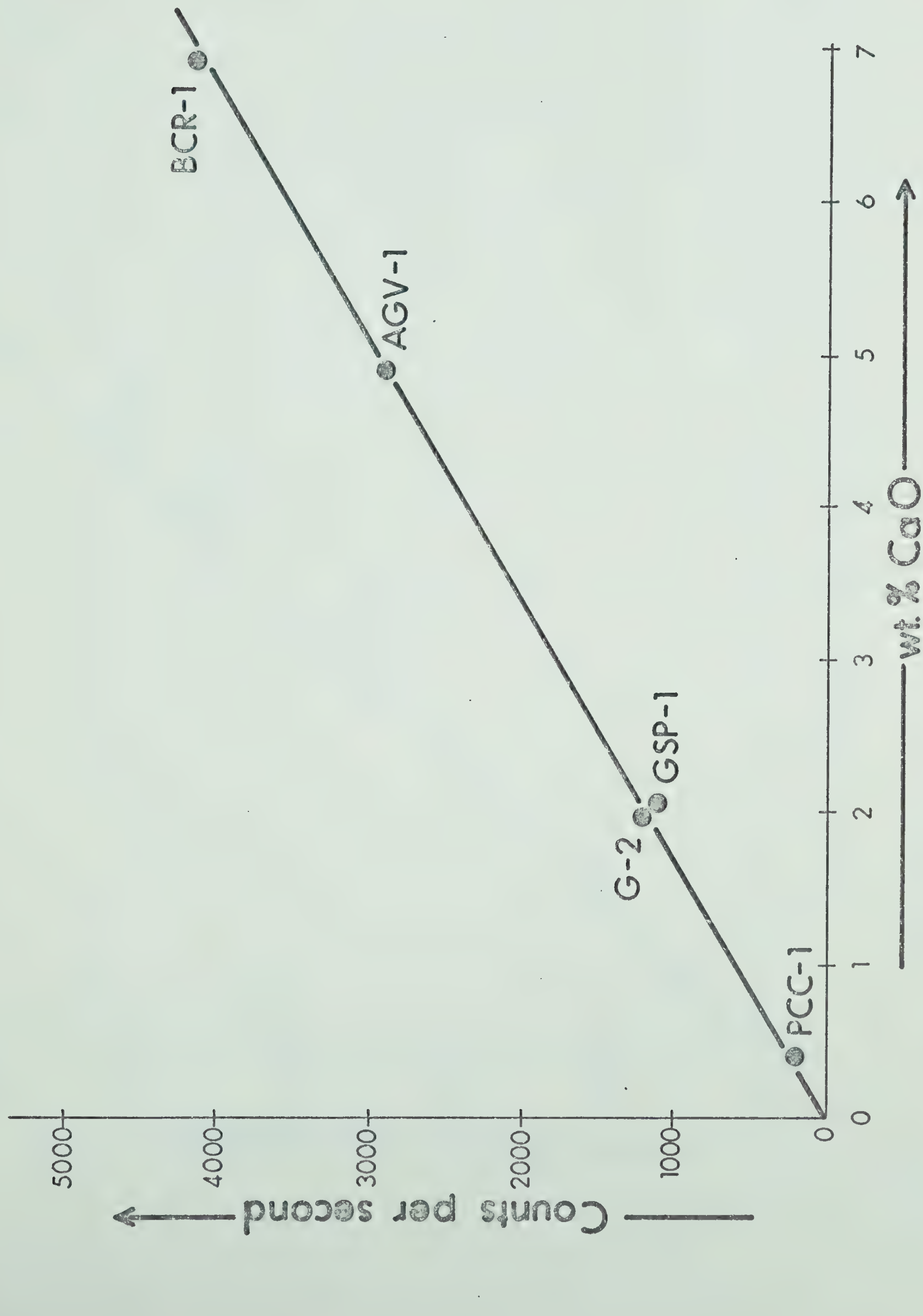

Fig.30: Calibration curve for CaO

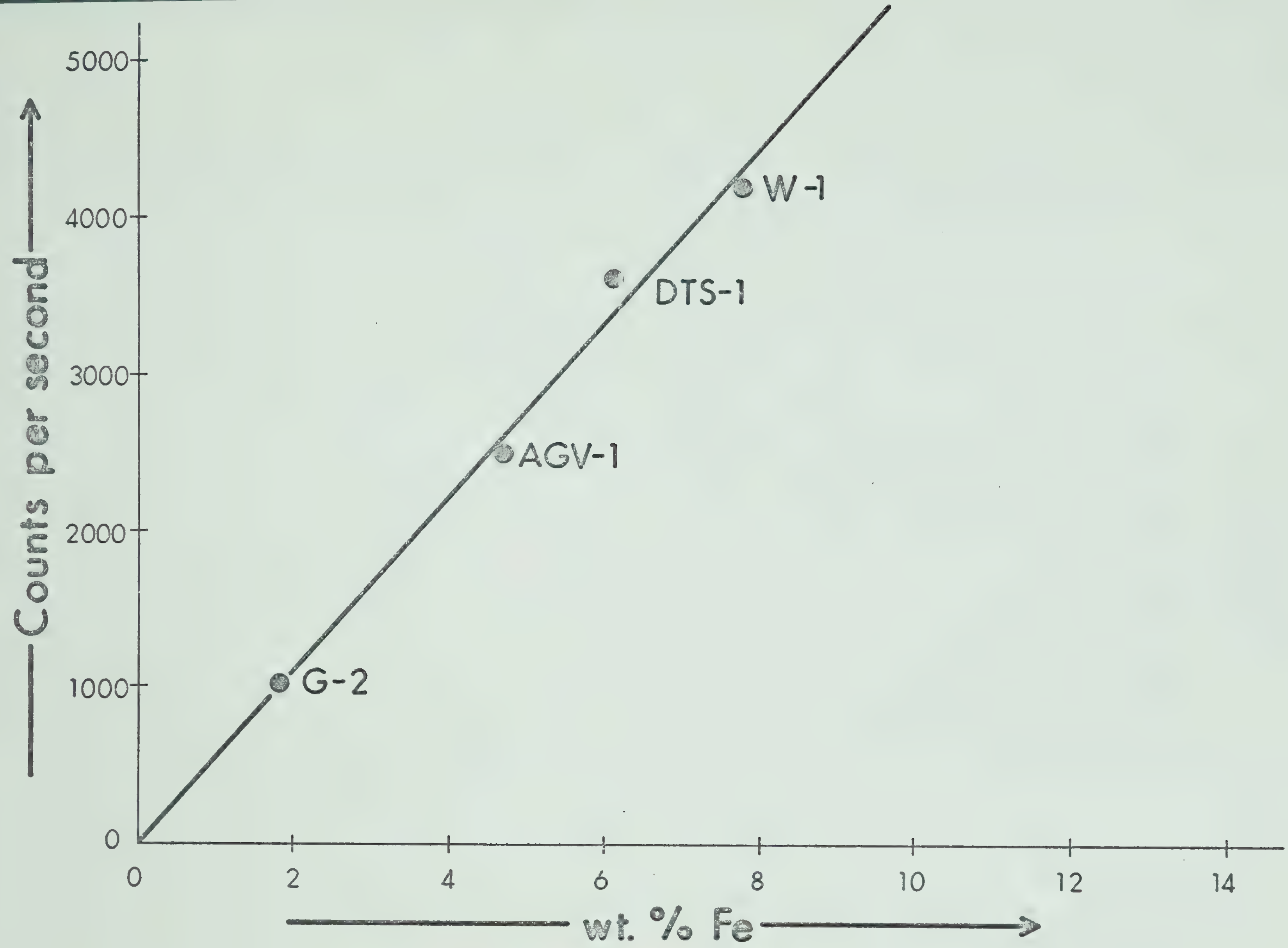

Fig.31 : Calibration curve for Fe

APPENDIX C

FLAME PHOTOMETRIC ANALYSIS

In sodium and potassium determinations, about 0.5 g of powdered sample was decomposed in a platinum dish by 5 ml of 1.1 H_2SO_4 and 10 ml of HF. After complete evaporation to dryness, excess H_2SO_4 was fumed off at about 400° C. The residue was moistened and transferred to a 50 ml beaker. The solution was leached three times and filtered into a 100 ml volumetric flask.

Analytical determinations were made on a Perkin-Elmer flame photometer, with capillary feed and constant air pressure. The estimated precision for Na^+ and K^+ is $\pm$ 0.5%.

APPENDIX D

PETROGRAPHIC DESCRIPTIONS OF ANALYZED SPECIMENS

SET-1: A fine grained biotite spilite with rather altered decussate laths and microlites of albitic-plagioclase, biotite and opaque iron-oxides, set in a groundmass of pale-green chlorite, carbonate and cryptocrystalline devitrification products. The approximate modal concentrations of the constituent minerals are: albite 75%, chlorite 15%, magnetite and ilmenite 6%, biotite 2%, carbonate and sericite 2%.

SET-6: Fine-grained spilitic lava with abundant plagioclase feldspar. The laths of plagioclase feldspar are commonly untwinned and occur as felted masses clouded with inclusions of sericite and chlorite. The opaque iron-oxides are magnetite and ilmenite, and they usually form euhedral to skeletal crystals. Chlorite and carbonate constitute the minerals in the groundmass. The estimated modal composition is as follows: plagioclase feldspar 84%. Opaque iron-oxides 10%, chlorite, sericite and carbonate 6%.

SET-7: Biotite spilite. This rock is fine-grained with felty texture. The plagioclase feldspar is albite and it shows both carlsbad and poly-synthetic twinning. Biotite, which occurs in random patches, is a golden-brown variety that is weakly- or non-pleochroic. It is intimately associated with the opaque iron-oxides. The matrix consists of chlorite and disseminated opaque iron-oxides. The approximate modal percentages of the mineral

constituents are as follows: albite 70%, biotite plus green mica 3%, chlorite and carbonate 10%, magnetite and ilmenite 8%.

SET-8: Porphyritic spilite. Phenocrysts with a plagioclase composition of sodic-oligoclase to albite are interspersed in a semi-trachytic, microcrystalline to cryptocrystalline mesostasis of albite, opaque iron-oxides, chlorite and carbonate. The phenocrysts show crude zoning defined by sericitic alteration. Inclusions of opaque minerals occur in the phenocrysts. Plagioclase feldspar constitutes 78% of the mode, chlorite and carbonate 10%, magnetite and ilmenite 12%.

SET-9: Biotite spilite. Fine-grained and fresh spilitic flow, comprising decussate laths of albitic-plagioclase, opaque iron-oxides and biotite, all randomly set in a groundmass of abundant chlorite and carbonate. Carlsbad twinning is common in the albite. The pale-green chlorite occurs in intersertal patches which may suggest a replacement of an original basic glass matrix.

SET-12: Fine-grained spilitic lava with thin laths of dominantly untwinned alkali feldspar, set in a groundmass of micro- to cryptocrystalline chlorite, and devitrified glass. Disseminated magnetite and ilmenite occur in patches. Alkali feldspar constitutes 70% of the mode, chlorite 13%, magnetite plus ilmenite 16% and carbonate 1%.

SET-14A: Porphyritic spilite. This rock is characterized by 2 mm long phenocrysts of albite to sodic-ologoclase composition. The

phenocrysts are usually prismatic crystals with compound lamellae. They are untwinned and twinned, with Carlsbad twinning being the most common. Inclusions of opaque iron-oxides and fracture-fillings of chlorite occur in the phenocrysts. The groundmass consists of microcrystalline and untwinned laths of albite, and intersertal patches of chlorite and opaque iron-oxides. Estimated modal percentages of the constituent minerals are: plagioclase 80%, chlorite 13%, ilmenite plus magnetite 7%.

SET-14: Magnetite spilite. Magnetite and ilmenite which occur as euhedral to subhedral, cubic to ragged crystals are relatively abundant in this lava. Hematite and leucoxene occur on the fringes of magnetite and ilmenite respectively. Euhedral laths of plagioclase feldspar of about 0.3 mm in length are common. Chlorite and carbonate constitute the matrix of the rock. Estimated modal percentages of the minerals present are: albite 73%, chlorite and carbonate 16%, biotite and opaque iron-oxides 11%.

SET-10: Porphyritic spilite. This rock is a fresh porphyrytic lava containing prismatic plagioclase phenocrysts of an average length of 3 mm. The groundmass is trachytic and consists of albite laths, chlorite, carbonate and opaque iron-oxides. Carbonate also occurs as veins. Plagioclase is 80% of the mode, chlorite 9%, carbonate 3% and magnetite plus ilmenite 8%.

SET-11: Amygdaloidal spilite. Large quartz amygdules, up to 6 mm in diameter, characterize this rock. Chlorite and pelucid albite

also occur as minor constituents of the amygdules. The most abundant mineral component of the rock is plagioclase feldspar of the albite variety, which occurs in an intersertal matrix of partly devitrified glass, chlorite, quartz and iron-oxides. The little amount of quartz in the matrix was introduced during the infilling of the amygdules. Estimated modal composition is as follows: albite 65%, quartz (amygdule and matrix) 10%, devitrified glass 18%, chlorite 3%, magnetite plus ilmenite 5%. Plagioclase feldspar comprises about 66% of the rock and magnetite plus ilmenite 24%. Chlorite, carbonate, sphene and hematite total about 10%.

SET-15: A fresh, medium- to coarse-grained lava exhibiting a fluidal texture. The plagioclase feldspar occurs as fresh lath-like crystals with infrequent albite twinning. Extinction angle measurements on sections parallel to 010 indicate an albite composition for the plagioclase. The mesostasis is composed of cryptocrystalline to microcrystalline feldspar, chlorite and disseminated opaque iron-oxides. The estimated modal composition is: albite 75%, magnetite plus ilmenite 12%, chlorite 13%.

SET-16: A carbonate-rich, fine-grained spilitic lava. The texture is prominently trachytic. Euhedral laths of albitic-plagioclase and opaque iron-oxides, are set in a groundmass of carbonate and chlorite. A small amount of the feldspar has been altered into sericite. The approximate modal percentages of minerals present are as follows: plagioclase 70%, chlorite plus green mica 6%, magnetite plus ilmenite 15%, and carbonate 10%.

SET-17: This lava is fresh and trachytic. Euhedral albite laths up to 0.2 mm in length constitute about 75% of the rock. Twinning in the albite is polysynthetic and Carlsbad, with the latter being predominant. Magnetite and ilmenite form euhedral to ragged crystals usually occurring in patches. Pale green chlorite is the major constituent of the groundmass. Magnetite and ilmenite constitute 9% of the mode, chlorite 15% and carbonate 1%.

SET-18: Amygdaloidal spilite. This rock is characterized by chlorite- and carbonate-filled amygdules, with an average diameter of 4 mm. Euhedral laths of predominantly untwinned and turbid alkali feldspar and opaque iron-oxides occur in an intersertal matrix of partly devitrified glass and chlorite. Sericite replaces some of the alkali feldspar. The approximate modal concentrations of the constituent minerals are: alkali feldspar 57%, magnetite plus ilmenite 10%, devitrified and opaque glass 28%, chlorite 3% and carbonate plus sericite 1%.

SET-19: Fine-grained, rather altered spilitic lava with decussate laths of predominantly untwinned alkali feldspar. Inclusions of chlorite and opaque dust cloud the feldspar. Magnetite and ilmenite are disseminated throughout the rock. The groundmass consists of intersertal patches of chlorite and pellucid albite. Patches of carbonate replace part of the groundmass. Approximate modal percentages of the minerals present are: alkali feldspar 78%, chlorite 15%, magnetite plus ilmenite 5%, and carbonate 2%.


DIABASE DIKE
ET—THEN GROUP
MURKY FORMATION
KAHOCHELLA GROUP
GIBRALTER FORMATION
SETON FORMATION
SOSAN GROUP
AKAITCHO RIVER FORMATION
KLUZIAI FORMATION
DUHAMEL FORMATION
Assumed fault
Approximate geologic boundary
Bedding, inclined, overturned
Bedding, vertical
Anticlinal axis
Synclinal axis
Axis of Anticlinorium and plunge direction
Cliff
Showing location
M C L E A N B A Y
Dyke Island
Sun Hill Island
Pratt Lake
Pontoon Lake
TOOPON LAKE
ROSE POINT
20°–25°
Musky Slough
MURKY RIDGE FAULT
FIGURE 8
GEOLOGICAL MAP
Toopon Lake Area,
Great Slave Lake, N.W.T.
SCALE 0 1000 2000 3000 FEET
M.A. Olade July, 1971.